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APPLIED MECHANICS REVIEWS

VOL. 13, NO. 6 JUNE 1960

A REVIEW OF THE DEVELOPMENT OF HIGH ENTHALPY AERODYNAMIC TEST FACILITIES

B. D. HENSHALL

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1. INTRODUCTION

Throughout the past decade a series of new aerodynamic test facilities have been conceived, designed and developed. The original stimulus for this work came from the ballistic missile program, but the subsequent space research program has ensured continuity of the effort to provide satisfactory high enthalpy aerodynamic test facilities. In 1954, during the initial stages of the development of experimental facilities, several differing approaches were made by isolated groups in research establishments; each group tended to concentrate on one particular facility for further detailed development. This early approach resulted, quite naturally, in a tendency for each group to emphasize its own contribution and so give the group an added incentive for the development of their particular facility. Unfortunately, this approach also meant that conflicting impressions of facility merits and limitations were given to administrators and others who were attempting to reach an unbiased yet critical assessment of the various test facilities under development.

In the past six years, the relative merits of the different types of high enthalpy aerodynamic research installations have been established by experiment and detailed analysis. At the present time it is possible to review the existing family of test facilities and to draw certain relevant conclusions which will be applicable to the design and performance of "second generation" experimental equipment for hypersonic research.

In the following sections some of the basic design requirements of high enthalpy research facilities are discussed briefly; a complete account of the simulation of full-scale conditions which are achieved in normal operation is given in reference (1). The spectrum of all possible hypersonic vehicles may be divided naturally into two distinct regions: first, those characterized by Mach numbers from 5 to 10 which fly continuously in the so-called "Flight Corridor" (see references (2) and (3)), and, second, those vehicles essentially characterized by Mach numbers of 20 which operate at or near orbital speeds and are capable of leaving and subsequently re-entering the atmosphere via the flight corridor. Examples of this latter class of vehicles are the DYNA-SOAR project (4) which is now under active development in the United States and the many existing ICBM rocket systems (5). These two main classes of hypersonic vehicles are usually termed "continuous cruise" and "re-entry" vehicles, respectively, and the requirement for laboratory simulation of these full-scale conditions has governed the development of experimental facilities.

In the present paper we will not discuss those wind tunnels which are devices for testing under essentially "ideal-gas" conditions; these tunnels have the prime object of avoiding liquefaction at the working section and may use unheated helium (6) or slightly heated air (7). Useful data may be obtained from such wind tunnels which are usually capable of operating continuously and have stagnation temperatures up to 1000°K. The high enthalpy tunnels which truly simulate the stagnation temperature and enthalpy encountered in full-scale hypersonic flight may be conveniently divided into two groups: those capable of operating continuously for periods of ten seconds or more, and those characterized by running times between 10 microseconds and 10 seconds. All these facilities reproduce the "real-gas" effects, such as ionization and dissociation, which occur in practical hypersonic flight at various altitudes.

2. "CONTINUOUS" FACILITIES

By the use of special types of storage heater or combustion heating, the performance of an ordinary supersonic/hypersonic wind tunnel may be extended to give flight simulation up to Mach 9, which corresponds to stagnation temperatures of about 2500°K. Similar conditions may be produced by rocket and ramjet engine exhausts (8). These installations may run for several minutes and can provide suitable conditions for structural testing appropriate to the "cruise" hypersonic vehicles. The re-entry vehicles require much higher stagnation enthalpy simulation and the only facility yet developed for this work is the "plasma-jet" (9) or electric arc wind tunnel (10) and (11).

This type of wind tunnel is exceptionally attractive and, although many problems remain to be solved, it will probably become the premier tool for large-scale hypersonic research in the future. Certainly it is essential for ablation studies and allied structural problems. At present, uncertainties exist about the spatial uniformity of the test section conditions and the thermodynamic composition and equilibrium of the test gas. Moreover, current arc-tunnels are limited (10) to stagnation pressures of 20 atmospheres and expanded flow Mach numbers of about 4. Improvements in electrode design and the use of magnetohydrodynamic techniques (12) can be expected to lead to the stagnation pressures required (say 50 — 100 atmospheres) but the extension of the Mach number range beyond $M = 9$ is

unlikely because of the need for an exceptionally high performance vacuum pump system to maintain the low pressure in the tunnel working section. Such a vacuum system would probably require a heat exchanger to be incorporated in the tunnel circuit downstream of the working section (11). It is to be expected that in five years' time large electric-arc hypersonic wind tunnels will be in the same stage of routine operation as the large supersonic tunnels are today. A typical installation would require 10 megawatts of power and run for 10 minutes; the working section may be 2 feet square with a flow Mach number of 8 and an enthalpy corresponding to $M = 25$ in the stratosphere.

While the large, continuous, electric-arc wind tunnel is essential for materials studies, aerothermoelastic tests, simulated trajectories, fatigue and life tests, much useful aerodynamic work may be done in very short duration flows in relatively cheaper facilities.

3. FACILITIES WITH SHORT RUNNING TIMES

The engineering problems involved when powers of 10 megawatts are dissipated in a wind tunnel for (say) 10 minutes may be drastically reduced by using running times of the order of milliseconds. The operating cycle of these facilities is so short that no provisions for cooling the wind-tunnel nozzle or models are necessary; indeed, the fundamental limitation on the tunnel running time is the time required to melt the nozzle throat.

If, in this brief period, the tunnel instrumentation can provide all or most of the aerodynamic data required, then the short-duration flow facility will be an important adjunct to the continuous installation. Moreover the short-duration facility has no upper limit on Mach number save that of flow liquefaction in the working section.

In retrospect, it would appear that the first short-duration tunnels were in advance of the instrumentation required, but intensive development of the instrumentation has now brought these tunnels to the verge of "fully-operational" status. Within the next year force measurements will become routine in addition to the pressure and heat-transfer measurements which are already commonplace.

We will now discuss the various types of short-duration wind tunnel which have been developed in the past decade. Basically these tunnels consist of various devices for producing high stagnation enthalpy test gas combined with a suitable nozzle, working section and dump chamber. Further details of the operation of each type of facility will be found in reference (1).

3A. Shock Tubes and Shock Tunnels

The straight shock tube (13) was, in 1954, already acknowledged as a useful, robust device capable of generating a flow of hot gas at a Mach number of about 3 with a duration of the order of 100 microseconds and a stagnation enthalpy and density appropriate to atmospheric re-entry (23). Much useful work on blunt shapes has since been done in the straight shock tube, particularly by the AVCO Research Laboratory (14 and 15). However, particularly for slender body studies, it was thought desirable to simulate the hypersonic flight Mach number in addition to the enthalpy appropriate to re-entry, and thus several groups embarked on the development of the shock tunnel; that is, a shock tube fitted with an expansion nozzle in which the hot gas produced by the shock tube is expanded to high Mach number. Hypersonic shock tunnels are now in operation at many research centers and details of their development and some typical results obtained are given in references (16) to (19).

Shock tunnels may be of two basic kinds: the straight through (or nonreflected) type and the reflected type. The latter type is capable of further subdivisions which are described in some detail in references (17) and (20). Experimental results (19) have demonstrated that the "straight-through" mode of operation is unattractive: under certain conditions the time required (21) to start the nozzle becomes equal to or greater than the available hot flow duration. Consequently, the reflected-type of shock tunnel, particularly in the "tailored-interface" operation (17), has superceded the nonreflected type for aerodynamic testing. Typical running times for the "tailored" and "straight-through" shock tunnels are 5 milliseconds and 0.5 milliseconds respectively for a simulated flight Mach number of 10.

The development of instrumentation has been rapid in the past few years and the frequency response and sensitivity of pressure gauges, accelerometers, strain gauges and resistance thermometers (for heat-transfer measurements) are now quite adequate for shock-tunnel work. The testing times required for a given flow observation are

1/5 microsecond for a flow photograph (24), (31)
5 microseconds for a heat transfer measurement (25), (26)
50 microseconds for a pitot pressure measurement (19)
200 microseconds for a static pressure measurement (27)
and 1,000 microseconds for a force measurement (28), (29), (34).

Unfortunately, the "tailored" shock tunnel will produce its maximum running time only at one stagnation temperature for a given combination of driver and driven gases; and it has been found experimentally (22) that the flow duration decreases rapidly on either side of the tailored condition. A shock Mach number range from 4.7 to 7.2 produced acceptable pressure records when using a hydrogen driver (which corresponds to a tailored shock Mach number of 6.1).

Tailored conditions may easily be produced in the range of shock Mach number from 4.1 to 6.1 by using a mixed helium and hydrogen driver (17). Above this stagnation temperature range of approximately 2000 to 4000°K, it would be necessary to heat the driver gas in order to produce the tailored condition. Preliminary experiments (30) have shown that it is possible to heat the driver gas to (say) 600°K and so extend the stagnation temperature range of the tailored interface shock tunnel to 5000°K.

For low stagnation temperatures, the test flow in a shock tunnel is terminated by the arrival of unsteady wave disturbances from the ends of the shock tube (13) (17) and, although increases in the lengths of the driver and driven tubes will alleviate this problem, a "barrier" to the unsteady flow disturbances is required. A piston in the driven tube is one appropriate solution: such shock tunnels with pistons are usually called Gun Tunnels.

3B. Gun Tunnels

Detailed performance studies for gun tunnels are presented in References (32) and (33). The gas at the entrance to the gun tunnel nozzle is compressed by a multiple shock reflection process which occurs between the piston and the end of the barrel. Eventually the piston comes to rest and as the gas subsequently expands through the nozzle, the piston moves towards the nozzle, reaching the nozzle entry when all the test gas has been consumed. The flow duration is limited by the time taken to melt the nozzle throat and/or by heat losses from the hot stagnant gas to the walls of the tunnel. Flows with stagnation temperatures up to 3000°K may be achieved, but most work so far reported has shown running times of 0.1 seconds at about 2000°K.

It is difficult to achieve large stagnation pressures with a gun tunnel because of the extremely high transient pressures associated with the initial multiple shock compression process. Figure 16 of reference (33) illustrates this point: a final steady stagnation pressure of 700 psi is associated with an "unwanted" peak pressure of 3500 psi.

3C. Hotshot Tunnels

The test gas supply may be heated by a direct electrical discharge rather than by the shock compression employed in the shock and gun tunnels. Arnold Engineering Development Center pioneered the electric-arc driven wind tunnel: subsequently this type of tunnel has become generally known by the label applied to the first one of its kind—HOTSHOT. Details are given in references (35), (36) and (37).

When the electrical energy is discharged, the air in the arc chamber is heated under constant volume (i.e. density) conditions and thus the final effective stagnation temperature may be calculated if the final effective stagnation pressure is measured.

The volume of a Hotshot arc discharge chamber is typically 30 cubic inches stressed to 4000 atmospheres, whereas in a shock tunnel the driver section is typically one cubic foot or more stressed to 1000 atmospheres.

In reference (38) an analysis is given which shows that the Hotshot offers substantial advantages over the shock tunnel for stagnation temperatures greater than 4000°K: at 6000°K the Reynolds numbers attainable in Hotshot tunnels are an order of magnitude greater than those produced by shock tunnels. Hotshots would appear to be pre-eminent for the study of very high enthalpy flows at re-entry Mach numbers.

The principal disadvantages of the Hotshot in its present form are the composition of the test gas (which is likely to be deficient in oxygen because of burning of the arc chamber lining and electrodes) and the changing reservoir conditions as the run proceeds. Research on electrode design may alleviate flow contamination (27) and computing procedures may be devised to allow for the variable reservoir conditions.

The running times achieved in Hotshots are quite adequate for pressure, heat transfer and force measurements (39) and are in the range 10 to 30 milliseconds (35).

3D. Moving Model Techniques

High-velocity guns may be used to project small models at velocities up to 17,000 feet per second into still air (34) or moving air in wind tunnels (40). The limited amount of instrumentation carried mitigates against the general utility of such facilities but full-scale conditions may be simulated and, in particular, valuable stability data may be obtained. Free flight model tests (3) must also play a vital role in the research program, but will not be discussed here.

4. DISCUSSION OF SHORT DURATION FACILITIES

4A. Gas Dynamic Properties of the Test Medium

Flow conditions in Hotshot tunnels will have some contamination present from electrode erosion and may also be oxygen deficient; shock and gun tunnels will produce very pure flows. Shock tunnels offer the most accurately known stagnation conditions which are obtained by inference from the measured shock velocity down the tube. Gun tunnels produce unwanted transients in stagnation temperature and pressure, and calculations of stagnation conditions from pressure records are clearly not so accurate as the corresponding calculations from shock velocity measurements. (This latter difficulty will apply to Hotshots also).

All these experimental facilities may suffer equally from nonequilibrium flow in the wind-tunnel nozzle (41) but recent evidence (42) shows that increase of stagation pressure is very beneficial and, by extrapolation, equilibrium flow is likely for expansion from a reservoir at 8000°K for stagnation pressures of 2000 atmospheres and above.

4B. The Spaceheater

From a survey of the different types of short-duration facilities, the domains of each type have been evaluated. Stagnation temperatures up to 2500°K are produced by the gun tunnel and this range is complemented and extended by the shock tunnel from 2000°K to 5000°K. The Hotshot (4000°K ⟶ 10,000°K) competes with the shock tunnel at the lower end of its range and is pre-eminent for stagnation temperatures of 5000°K or more.

By careful initial design it is possible to arrange for the reservoir of hot gas which drives the tunnel to be provided by a shock, a piston or an arc. This type of tunnel might be labelled a

SPACEHEATER

that is a *S*hock, *P*iston, *A*rc *C*ombination *E*quipped *H*igh *E*nthalpy *A*erodynamic *T*unnel for *E*xperimental *R*esearch.

In the present writer's opinion, a SPACEHEATER represents a logical development from existing short-duration facilities: detailed design in the initial stages should yield handsome dividends in flexibility of operational use.

5. CONCLUSIONS

From a review of the development of high enthalpy aerodynamic test facilities it is concluded that the large, expensive, arc-heated continuous wind tunnel is the ultimate structural and aerodynamic installation. Nevertheless, much useful aerodynamic work can be done in cheaper short-duration facilities; the SPACEHEATER represents a logical development of the present generation of gun tunnels, shock tunnels and Hotshots. Attention is drawn to the uses of the free-flight model testing in ground ballistic ranges and in the upper atmosphere.

In the past decade, results obtained from high enthalpy facilities have progressed from laboratory curiosities to routine research data: it can reasonably be expected that, by 1965, these facilities will be as commonplace as large supersonic wind tunnels are today.

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(See also Revs. 2685, 2693, 2696, 2700, 2705, 2713, 2716, 2732, 2733, 2750, 2761, 2772, 2786, 2787, 2791, 2794, 2795, 2838, 2903, 2909, 2933, 3024, 3055, 3065, 3066, 3120, 3123, 3126, 3189, 3192)

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For a review of the first edition see AMR **8** (1955), Rev. 9. The second edition contains a new 48-page chapter which applies L. Schwartz' theory of distributions to initial-value problems. Otherwise, except for minor changes and additions, the two editions are the same. The new chapter contains a brief introduction to the calculus of distributions and applications of theory to three-dimensional stationary supersonic flow problems. A section on the use of Laplace transforms, particularly transforms of distributions, is also included. R. A. Clark, USA

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R. M. G. Muller, Indonesia

2674. Becker, H., The reciprocal method and its application for finding approximate solutions of nonlinear differential equations (in German), *Regelungstech.* **7,** 5, 168–170, May 1959.

The reversion method makes it possible to find the (approximate) solution of a nonlinear differential equation by solving a sequence of linear differential equations. The basic relations of the method are given and their application is demonstrated in three examples.

From author's summary

Book—2675. Fenyo, I., Integral equations [Integralegyenletek], Budapest, Tankonyvkiado, 1957, 180 pp. 17 Ft. (Paperbound)

Book (181 pages) consists of summary of the theory and use of integral equations (about 60 pages) and discussion and solution of 259 illustrative problems (about 120 pages). It is one of a series of books on applied mathematics prepared for analytically inclined students and engineers at the Polytechnic Institute. The topics treated range from Fredholm and Volterra theory through numerical approximations, potential theory and Green functions, to singular integral equations. Because of the recent emergence of integral equations as a basic tool of applied mathematics, book is a very welcome addition to the literature. In presenting the subject from the point of view of problem solving and compilation of available results, it fills a basic void in the literature. One wishes that a translated version—with, perhaps, a more extensive treatment of singular integral equations—would become available in the future.

G. Horvay, USA

Book—2676. Acton, F. S., Analysis of straight-line data, New York, John Wiley & Sons, Inc., 1959, xiii + 267 pp. $9.

Reviewer recommends this interesting book to any scientist or engineer confronted with the task of analyzing experimental data containing one or more lines. The chapter headings indicate the areas covered: The choice of a model; The classical model (x known without error; variance of y constant); Regression with several values of y for each known x; Samples from bivariate normal populations; Regression with both x and y in error; Several lines (the analysis of variance); The exposure of curvature (orthogonal polynomials); The use of transformations; Rejection of unwanted data; Cumulative data (the fading line). A modest background in probability, statistics and college mathematics is required.

Reviewer agrees with author that there is little point in employing a great deal of mathematics which is not really required. However, the omission of a definition of a random variable and an attempted justification of this omission appears to be going too far in the nonmathematical direction. In spite of this minor point, the book is a welcome addition to applied statistics literature.

J. L. Bogdanoff, USA

2677. Chekhonadskii, N. A., Utilization of the theory of random functions in metrology, *Measurement Techniques* no. 2, 121–126, Aug. 1959. (Translation of *Izmeritel'naia Tekhnika, USSR* no. 2, 3–7, Mar./Apr. 1958 by Instrument Society of America, Pittsburgh, Pa.)

The theory of random functions, developed by Pugachev, is used for obtaining an estimate of the error of a measuring system of a number of separate links, such as a transducer or transmitter, an electrical circuit network, a measuring instrument, etc. It is shown that, when the measured quantity remains constant, the resultant error may be expressed in the form $\Delta = \Sigma \alpha_i \Delta_i$, where Δ_i is the error of the i-th link of the measuring system and coefficients α_i are determined by $\alpha_i = \frac{S_{(i+1)n}}{S^*_{(i+1)n}}$, $S_{(i+1)n}$ being the sensitivity of the truncated measuring system with the links from $i + 1$ to n retained, and $S^*_{(i+1)n}$ the sensitivity of the same portion when all links in this portion are linear. Result is then extended to the case when the errors of links are random functions of time.

G. Supino, Italy

2678. Bellman, R., and Dreyfus, S., Functional approximations and dynamic programming, *Math. Tables Aids Comput.* **13,** 68, 247–251, Oct. 1959.

Problems in calculus of variations involving functionals in N-dimensions lead to need for immense short memory storage facilities when numerical techniques are used based on values of function at lattice points of an N-dimensional grid. Author replaces functions by orthonormal power series,—in particular, Legendre polynomials—and determines coefficients by means of mechanical quadrature formulas based on tabulated quantities. Storage is then required only for coefficients. Method is not justified for one dimension but is increasingly useful for $N > 1$.

R. D. Milne, England

2679. Finch, P. D., Balking in the queueing system GI/M/1, (in English), *Acta Math., Acad. Sci. Hungaricae* **10,** 1/2, 241–247, 1959.

Balking is defined as the departure from the queue of a customer who finds n customers ahead of him. Barrer has used the term "impatient customers" in a previous paper [*Oper. Res.* **5,** pp. 644 and 650, 1957; AMR **11** (1958), Revs. 1454, 1455] dealing with a related problem. The problem treated here is the single-server queue with a general input and exponential service on first-come-first served basis, the maximum size of the waiting facility can have any value, and the balking process can be random or deterministic. Finch proves that if the input distribution is not a lattice distribution then a limiting distribution of the balking probability exists and is independent of the initial state. He obtains the state probabilities for the balking system. The results of Haight [*Biometrika* **44,** p. 360, 1957] for Poisson input and infinite waiting capacity and Takács [*Ann. Univ. Sci., Budapest, Seetio Math.* **1,** p. 73, 1958] for deterministic balking are shown to be special cases of the general formulation of this paper. Takács, it must be noted, has also treated this case for the many-server problem. Barrer's problem is not listed, but since it deals with balking as a function of the time spent in waiting, it too should be a special case of this general problem.

E. Koenigsberg, USA

2680. Gani, J., and Prabhu, N. U., The time-dependent solution for a storage model with Poisson input, *J. Math. Mech.* **8,** 5, 653–663, Sept. 1959.

The problem discussed is the determination of the probability of emptiness of an infinite reservoir with Poisson input and a steady continuous release (except, of course, when the reservoir is empty). The probability of emptiness at time t, $F(0, t)$ is obtained after first finding the probability of first emptiness of the reservoir, by following a similar procedure enumerating the ways in which the reservoir may empty and then summing the probabilities for the various ways. The probability of emptiness, in either case, is a function of the initial state. Having calculated the probability of being empty one can then proceed to solve the forward Kolmogorov equation directly. The Kolmogorov equation is given by

$$\frac{\partial}{\partial t} F(z, t) - \frac{\partial}{\partial z} F(z, t) = -\lambda [F(z, t) - F(z - b, t)], \quad 0 \leq z < \infty$$

where b is outflow and λ the mean input in time interval t. The steady-state distribution of the dam content can then be derived as the limit of $F(z, t)$ as $t \to \infty$. When $\lambda b < 1$, in the limit $t \to \infty$, we have

$$F(z, 0) = \phi(z) = 1 - \lambda b \sum_{r=0}^{z/b} e^{-\lambda(rb-z)} \frac{\lambda (rb - z)^r}{r!},$$

which is the result of Takãs [*Acta. Math., Acad. Sci. Hungaricae* **6,** p. 101, 1955]. The time-dependent solution is not found elsewhere. E. Koenigsberg, USA

2681. Luke, Y. L., Expansion of the confluent hypergeometric function in series of Bessel functions, *Math. Tables Aids Comput.* **13,** 68, 261–271, Oct. 1959.

In previous expansions of $\phi(a, c, z)$ in terms of modified Bessel function $I_n(w)$, both n and w depended on a and c. Author's expansion is in terms of $I_k(z/2)$ where k is running integer, thus simplifying use in numerical calculations. Price of this simplification is complicated series coefficients $R_k(a, c) = {}_3F_3(-k, k, a; c, \tfrac{1}{2}; 1)$. Author obtains recursion and asymptotic forms for $R_k(a, c)$, develops expansions for incomplete gamma function and exponential integral, and gives numerical examples to demonstrate improved convergence. V. Salmon, USA

Computing Methods and Computers

(See also Revs. 2681, 2689, 2690, 2726, 2761, 2783, 2791, 2824, 2853, 2874, 2965, 3008, 3092, 3123, 3125)

2682. Baker, G. A., Jr., and Oliphant, T. A., An implicit, numerical method for solving the two-dimensional heat equation, *Quart. Appl. Math.* **17,** 4, 361–373, Jan. 1960.

Authors introduce a finite difference method for numerical treatment of the heat equation $\theta_{xx} + \theta_{yy} = b\theta_t$. In the case b = const a difference scheme is chosen such that the two-dimensional set of implicit equations may be factorized into two one-dimensional sets which may be solved exactly. The procedure is then augmented by an iteration process to include the case $b = b(x, y, \theta)$. The method is proved to be unconditionally stable in cases b = const and $b = b(x, y)\,\theta^\gamma$ where $-2 < \gamma \leq 0$ and $|b(x, y)| < \infty$; the mesh size and the time step influence only the accuracy, not the stability. As an illustration of the method the IBM 704 calculations for the cases b = const and $b = \theta^{-3/4}$ for a rectangular region are described. O. B. Hellman, Denmark

2683. Mitchell, A. R., The influence of critical boundary conditions on finite difference solutions of two point boundary value problems, *Math. Tables Aids Comput.* **13,** 68, 252–260, Oct. 1959.

The object of the present note is to illustrate by means of worked-out examples the extent of the disagreement which often exists, even for small mesh lengths, between corresponding exact solutions of ordinary differential and difference equations.

From author's summary by D. C. Leigh, USA

Book—2684. McCracken, D. D., Weiss, H., and Lee, T.-H., Programming business computers, New York, John Wiley & Sons, Inc., 1959, xvii + 510 pp. $10.25.

This book assumes little or no previous knowledge of computers, and is written for the person who needs to acquire either a general or a detailed knowledge of the way they work and how they can be used in business. Coding occupies eight chapters out of a total of twenty-one; it is treated in terms of a mythical computer, DATAC, which has the features common to most actual computers. A person interested in some particular machine can skip sections dealing with features his machine does not possess. Other sections of the book deal with miscellaneous background material needed for an understanding of digital computers; with such advanced topics as sorting on a computer, automatic coding, economizing and estimating computer time; with the planning of computer applications, and with the accounting and auditing problems involved in automatic data processing. An appendix gathers together the details of the DATAC machine, and treats the binary number system.

The book requires no mathematical or engineering background. It is very clearly written, and every person interested in the business use of computers will find it extremely valuable. It is at least twice as large a book as McCracken's "Programming for digital computers" (which is concerned with scientific uses), but, as is to be expected, where the topics of the two books overlap there is some similarity of treatment. The highly readable prose style is common to both works. R. T. Harling, USA

2685. Archer, J. S., Digital computation for stiffness matrix analysis, *Proc. Amer. Soc. Civ. Engrs.* **84,** ST 6 (*J. Struct. Div.*), Pap. 1814, 16 pp., Oct. 1958.

2686. Rose-Innes, A. C., Refrigeration of a superconducting memory for a computer, *Brit. J. Appl. Phys.* **10,** 10, 452–454, Oct. 1959.

An estimate is made of the refrigeration, in terms of consumption of liquid helium, required to maintain at low temperature a memory of superconducting cells. Using commercially available cable, the major source of heat is thermal conduction down the leads to the memory. If a cable of low thermal conductivity is used, a memory of one million cells should not consume more than about 2 l. of liquid helium per hour. In an appendix, the optimum size for copper electrical leads running directly from room temperature to liquid helium is calculated.

From author's summary

2687. Neustadt, L., A method of computing eigenvectors and eigenvalues on an analog computer, *Math. Tables Aids Comput.* **13,** 67, 194–201, July 1959.

Whereas for digital computers a trial and error method is required, using the analog computers the eigenvectors and eigenvalues can be computed directly. The reader should be familiar with matrix algebra, solution of differential equations and with the general set up of analog computers. The solution procedure has been worked out for linear programming, although nonlinear programming is possible. It is based on the geometrical and mathematical relationship that a point on the surface of a unit sphere moves until it reaches a steady state corresponding to the maximum of the function of $\{A\}\{X\}\{X\}$, where $\{X\}$ is the radius vector to the point $x = (x_1, x_2, \ldots x_n)$ in n space.

The engineering significance of the solution lies in the application of finding eigenvalues of a vibrating system having many degrees of freedom. R. Szilard, USA

2688. Dove, D. B., Simple electrical analogue for the solution of linear simultaneous equations, *J. Sci. Instrum.* **36,** 11, 474–475, Nov. 1959.

Analogies

(See also Revs. 2680, 2698, 2907)

2689. Shields, J. H., and MacNeal, R. H., The solution of elastic stability problems with the electric analog computer, *ASME Trans.* **81E** (*J. Appl. Mech.*), 4, 635–642, Dec. 1959.

In the present paper, which may be regarded as an interesting and valuable contribution to the problem of electric analog computing methods, a modified analogy allowing inclusion of axial load effect is described. General form of equation dealt with is $(Aw'')'' - [(a - b \cdot N_x)w']' + (c - d \cdot N_x)w = q$ where A, a, b, c, d, q are coefficients and N_x are eigenvalues of the elastic stability problem. From this equation, replaced by a set of four infinite difference equations, an elementary electrical circuit containing inductors, capacitors and transformers is devised. Repeating and modifying this elementary unit more complicated networks can be composed to obtain electrical analogies for buckling of a column with hinged and clamped ends, buckling of beam on elastic foundation, buckling of a frame and flat plate, a simple angle, etc.

To obtain the buckling load for a structure from its analogous circuit the frequency of driving voltage is varied and frequencies of extremal impedance determined. Very close agreement between theoretical and experimental results was found.

It is believed that the techniques described can be extended to many other problems of elastic stability.

K. Julis, Czechoslovakia

2690. Renard, G., Direct representation with the rheoelectric analogy of the gradients of harmonic functions in bounded or unbounded two-dimensional domain (in French), *Publ. Scient. Techn. Min. Air. France, Notes Tech.* no. 78, 116 pp., Dec. 1958.

Author introduces a new technique of field evaluation by means of rheoelectric analogy by which gradients of harmonic functions can be obtained as point functions rather than differentials of potential evaluated over two adjacent field points. This is accomplished by a simple mathematical property of analytic functions whereby the gradients of a potential field can be characterized by the modulus and argument of logarithmic derivative of a complex potential. Thus the rheoelectric analogy is applied to the logarithmic derivative of the complex potential to obtain the gradient field for such cases as flow around profiles, flow through cascades, jet flow, heat conduction problem and problem involving nonhomogeneous magnetic field.

The advantage of the proposed method is obvious since it eliminates the complexity of apparatus or great deal of labor involved in determination of field gradients by numerical differentiation of potential field. On the other hand, the limitation of this method lies in the difficulty of analytically transforming the boundary conditions imposed on the potential field into corresponding conditions valid with regard to the logarithmic derivative of this field.

B. Zarwyn, USA

2691. Juniewicz, S., and Aulich, J., Aerohydrodynamic analogy and its application to the model tests of hydraulic structures (in Polish), Wroclaw Polytechnic Institute, Scientific Meeting, Dept. Continental (Civil) Engng. Rep. 9, 16–20, 1958. (Referaty, Wroclaw, 259–266, 1958).

Model of shifting river bed is subjected to an air stream instead of water. Influence of gravity is eliminated, inertia and viscosity forces are the only variables. Model can be very small, the scale ratio is not very important. Tests require less time; it is easy to establish and to change the air flow. This method was originated by L. Escande in France in 1950, and was successfully applied in Poland. S. Kolupaila, USA

2692. Einstein, H. A., and Harder, J. A., An electric analog model of a tidal estuary, *Proc. Amer. Soc. Civ. Engrs.* **85,** WW 3 (*J. Water. Harbors Div.*), 153–165, Sept. 1959.

Five hundred miles of channel in the Delta Region, California, now subject to sea water encroachment, may be protected by salinity barriers and a master levee system. An electric analog model developed at the University of California predicts tidal amplitude and flows resulting from such modifications to the hydraulic system. From authors' summary

Kinematics, Rigid Dynamics and Oscillations

(See also Revs. 2673, 2788, 2791, 2893, 2894, 3121, 3122)

2693. Bogoiavlenskii, A. A., On some special solutions of the problem of motion of a heavy rigid body about a fixed point, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **22,** 6, 1049–1064, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N.Y.)

Article deals with mathematical aspects of the title problem and presents analytical techniques to find solutions of prescribed types under several restrictions on initial conditions and mass distribution of the body. Methods are based on previous results by the author [title source **22,** 5, 1958]. Equations of motion used are those of Hess-Schiff type, involving as dependent variables ν (essentially angular momentum squared), τ (essentially kinetic energy) and ρ (projection of angular momentum on radius vector of center of gravity). Assuming that ν, τ, ρ may be expanded in powers of time with the origin as a pole, coefficients of the expansions are determined, after substitution in corresponding equation, by equating coefficients of equal powers. These expansions are substituted in other reduced equations with the further assumption that ν and τ are polynomials of degree n in ρ, and new coefficients are determined.

Then author obtains conditions which are to be imposed on initial values of energy and vertical component of angular momentum and on principal moments of inertia, in order to obtain the desired type of solutions. Performing several transformations on dependent or independent variables, and applying the same general procedure, solutions are obtained which correspond to various special cases already known. Apart from this, no new cases are obtained.

Reviewer believes outlined procedure is very convenient for a general discussion of the title problem, although calculations are rather tedious. A few misprints escaped correction. A useful table is given of equivalent symbols used by different authors.

W. W. Lubomirsky, Argentina

2694. Hohenemser, K. H., Contribution to the dynamics of rotating wings (in German), *Ing.-Arch.* **28,** 99–108, Mar. 1959.

Probability of self-excited vibrations or instability of rotating wings is best determined by combination of model experiments and electronic computer studies, preferably of analog type. Former is more accurate, but latter has more flexibility and wider range; methods complement and check each other. In this paper various types of self-excited disturbances are defined, explained, calculated, plotted with generalized parameters; model and calculated

results are compared. Results should be of interest to helicopter designers. C. W. Smith, USA

2695. Wilson, R. H., Jr., A gravitational force function for the earth representing all deviations from a spherical geoid, *J. Franklin Inst.* **268,** 5, 378-387, Nov. 1959.

In the present treatment each area of deviation from a uniform spherical gravitational field is represented by a separate series of Legendre polynomials having its pole of reference centered on the area. Thus the Earth's north and south polar oblateness deviations are represented separately so that their inequality can be investigated. The series for minor deviations centered at general latitudes and longitudes has been transformed to terms of variables in the inertial coordinate system for practical computation. The vector sum of these expressions for the Earth's spherical gravitational field and its deviations, together with explicitly presented geocentric expressions for the fields of the moon and sun, would thus constitute a complete force function for satellite orbit development by numerical integration.

From author's summary by W. W. Berning, USA

Book—2696. Crandall, S. H., edited by, Random vibration (Notes for the MIT special summer program), Cambridge, MIT Technology Press, 1958, vii + 400 pp. $10. (Paperbound)

The twelve chapters of this book are the lecture notes for the 1958 MIT Special Summer Program on Random Vibrations given by eleven specialists, chiefly in the field of mechanical vibrations. It presents a survey of recent progress in the extension to this field of the type of random spectral analyses which have been achieved in the theories of electrical noise and turbulence.

Chapter 1, Mechanical vibrations with deterministic excitation (by S. H. Crandall), Chapter 2, Description of random processes (by W. M. Siebert), and Chapter 4, Stochastic processes of mechanical origin (by Crandall), provide the mathematical and statistical background for the theory and problems discussed in most of the chapters. The material of these introductory chapters can be found in the books of Laning and Battin [AMR **9** (1956), Rev. 3835] and of Davenport and Root. These chapters, although adequate for the material to follow, could have been better written, giving the reader more perception into the processes to follow.

Chapter 3, Stochastic processes of mechanical origin (by H. Poritsky), presents an instructive collection of statistical problems arising out of random imperfections of surfaces of contact between bodies such as bearings and gears, random reflections, random walk, statistical mechanics, and turbulent flow. This very interesting survey chapter should have an extensive bibliography and does not. Chapter 5, Structural damping (by T. H. Pian), is chiefly a review of some experimental results illustrating differing characteristics of mechanical structural damping due to slippage between system parts and to internal friction. Random aspects are scarcely mentioned. Similarly, random features receive minor mention in the next chapter, Fatigue of metals (by F. A. McClintock), which presents a good survey of mostly experimental results shedding light on the mechanism of fatigue and such factors affecting its propagation as repeated stress and varying loads.

Chapter 7, Instrumentation for random vibration analysis (by T. P. Rona), is a well-organized and well-written survey of transducers and vibration detector transfer characteristics, signal transmission, processing, and techniques of spectral analysis. It should be of value to the research and development engineer wishing an introduction to these techniques.

Chapter 8, Response of structures to random structures and to jet noise in particular (by Alan Powell), and Chapter 9, Estimation of sound-induced missile vibration (by Ira Dyer), present a good discussion of the responxe of structures to random pressure excitations due to jets and rocket engines. Chapter 8 is theoretical and assumes a higher level of mathematical sophistication. It presents the resultant linear theory by the method of normal modes, accompanied by some examples. The first part of Chapter 9 discusses the nature of the noise field while the latter part is concerned with several varieties of response; e.g., in the presence of liquid loading, and the step-by-step presentation of the handling of the vibration problem of a hypothetical missile.

Chapter 10, Basis for the design of simulation (by K. J. Metzgar), briefly and weakly treats the philosophy of design of random vibration test equipment centering on the electrodynamic shaker which could be used as a simulator of a motion generator or of an energy source and in the simulation of failure. Chapter 11, Technical characteristics of simulation equipment (by D. E. Priest), continues with the details of these systems, the response of shaker equalizers, random noise signal generators and shapers. The resonance-induced problems and their possible solutions are also discussed.

The final chapter 12 by R. M. Mains is a collection of four papers on "Mechanical design for random loading" discussing such topics as the probable response of systems with many degrees of freedom under random excitation, cumulative fatigue damage, and the minimization of damage from random vibration.

The wide range of random mechanical vibratory phenomena and related problems treated, extensive bibliographies for most of the chapters, and the scholarly treatment of their topics by most of the authors are attractive features of this book. On the negative side, assuming that a main purpose of technical books is exposition of theories and techniques of solution of *classes* of problems rather than problems, there should have been more integration of the later chapters with the chapters on the underlying mathematical and statistical theories. For example, the central role played by the ergodic theorem is not mentioned outside of Chapters 2 and 4. It would also have been desirable to have some indication of numerical bounds on the total errors accumulated not merely from the experimental equipment *per se* but from such items as finite times in the determination of time averages. Most of the errata have been caught and included on a separate sheet, although there still are few inaccurate statements in the mathematical sections that will disturb the discerning reader. M. L. Juncosa, USA

2697. Hsu, C. S., On the application of elliptic functions in non-linear forced oscillations, *Quart. Appl. Math.* **17,** 4, 393-407, Jan. 1960.

The author studies various exact solutions of the differential equation [1] $x'' + x + \beta x^3 = F(\tau)$ ($' = d/d\tau$). When $F \equiv 0$ (free vibrations) the solutions of [1] are elliptic functions. It is then shown that if $F(\tau)$ is one of a class of elliptic functions, [1] still has solutions which are elliptic functions. The results are illustrated with graphs showing variation of frequency of response with amplitude. The case that $F(\tau)$ is a sinusoid is then studied, $P_e \cos \omega r$. The author shows how the solutions in the sinusoidal case can be approximated by various elliptic functions. The standard sinusoidal approximations obtained by methods like that of van der Pol (cf. Stoker, Nonlinear vibrations, Interscience, 1950) are obtained by this method. The paper concludes with a study of subharmonic solutions of [1] which are elliptic functions.

W. S. Loud, USA

2698. Christiansen, J. N., Transient motion in mechanical wave-filters, Proc. Third U. S. Nat. Congr. Appl. Mech., June 1958; Amer. Soc. Mech. Engrs., 1958, 117-121.

For a system equivalent to an infinite chain of pendulums coupled by springs attached to hinge points along rigid arms, author first obtains steady-state response to sinusoidal motion of one mass in closed form. A formal solution in terms of two integrals is then obtained for free motion with arbitrary initial conditions and these integrals are solved for two special cases. The

formal solution for arbitrary forced motion is obtained from that for arbitrary initial conditions by Duhamel integration.

F. L. Dimaggio, USA

Instrumentation and Automatic Control

(See also Revs. 2677, 2816, 2836, 2860, 2869, 3070, 3087, 3120, 3126, 3130, 3132, 3191)

2699. Rogers, M., and Shapiro, G., Performance of closed-loop flip-flop control systems in missiles and rockets, AFOSR TN 59-349 (Westinghouse Corp., Air Arm Div.; ASTIA AD 213 677), 66 pp., Apr. 1959.

This report is devoted to the on-off control of the roll of an aerial vehicle with pitch and yaw neglected. The vehicle is described by a linear second-order differential equation with constant coefficients in which damping and inertia effects are taken into account. The control function has proportional and derivative terms. It is assumed that there is a time delay in the controlled system and that the "on-of" forcing function builds up linearly with time to saturation values, instead of instantaneously. The effect of variations in system parameters on performance is determined with the aid of the phase plane. R. Oldenburger, USA

2700. Kulikowski, R., Concerning the synthesis of the optimum nonlinear control systems (in English), *Bull. Acad. Polonaise Sci.* **7**, 6, 391-399, 1959.

Optimum control is defined here as the requirement that the output of a given system and its derivatives should equal the desired output and its derivatives in the shortest possible time subject to certain constraints. The constraints are that either the control signal has a bounded magnitude M or that its mean square value P is bounded. Author solves problem of determining the minimum possible time T (for given M or P) and the corresponding optimum control signal for the two cases of linear and nonlinear fixed elements using results obtained in his previous paper [*Bull. Acad. Polonaise Sci.* **7**, 4, 285-294, 1959]. For bounded control signal and linear fixed elements, details are given of the optimum control system which is essentially a race-brake system with switching instants governed by nonuniformly sampled error signal. Analytical description is given of an optimum system with nonlinear fixed element of form $u_2 = a_1u_1 + a_3u_1^3$ and bounded control signal.

R. J. Kavanagh, England

Tables, Charts, Dictionaries, etc.

(See Rev. 2790)

Elasticity

(See also Revs. 2730, 2742, 2745, 2750, 2758, 2759, 2772, 2774, 2775, 2787, 2816, 2821, 2823, 2831, 2847, 2860, 2861, 2869, 3041)

Book— 2701. Pearson, C. E., Theoretical elasticity (Harvard Monographs in Applied Science no. 6), Cambridge, Mass., Harvard University Press, 1959, 218 pp. $6.

The basic theme of this book is to discuss modern methods of elasticity theory in a form which does not require an extensive mathematical background. The author briefly introduces the reader to vector analysis, tensor analysis, and differential geometry in the first two chapters. The third chapter is devoted to tensor representations of stress as well as equilibrium equations for three-dimensional systems. Chapter four presents an exceptionally clear exposition of Lagrangian and Eulerian variables and the corresponding strain tensors for small deformations as well as the general nonlinear case.

The basic equations of linear elasticity and relations between elastic constants are presented in the fifth chapter. Particular attention is given to concentrated force situations and corresponding singularities. The sixth chapter presents a discussion of many methods of solution, such as the use of Green's function; representations due to Betti, Kelvin, Boussinesq, Papkovich-Neuber, Galerkin, and Maxwell-Morera. The function space method due to Prager and Synge is presented in detail.

Reformulation of the elasticity equations in terms of equivalent variational conditions is the subject of the seventh chapter. The techniques of virtual work, Rayleigh-Ritz, Lagrangian multipliers, minimal potential, and complementary energy are presented in general terms. A review of elementary thermodynamics is given at the start of the eighth chapter. This is followed by a discussion of adiabatic and isothermal moduli and a formulation of the thermoelastic problem.

Time-dependent problems are formulated in general terms in the ninth chapter. The discussion centers largely around elastic waves and Rayleigh surface waves. A brief exposition of elastic vibrations concludes the chapter. Nonlinear elasticity constitutes the topic of the tenth and last chapter. Both geometric and materail nonlinear effects are considered. The problem of elastic stability is briefly mentioned as an application of this phenomena.

Throughout the book emphasis is on general results and techniques of solution. Few illustrative examples are presented. The book is the result of the author's lectures to graduate students in applied mechanics. It would also be suitable as a reference book for the person somewhat familiar with techniques of solution who wishes to gain a knowledge of the relations between the well-known special techniques so as to have a well-integrated picture of elasticity theory. W. A. Nash, USA

2702. Goded, F., The stress function of a radial strain, *ASME Trans.* **81**E (*J. Appl. Mech.*), 3, 440-441, Sept. 1959.

The state considered is that of wholly radial displacement. Its magnitude is found to be of the form $u = \phi/\mu R^2$, where the stress function $\phi = R^{4\nu-2} \cdot \varphi(\theta, \psi)$ in the spherical polar system (R, ψ, θ), and $\varphi(\theta, \psi)$ satisfies a second-order equation. The condition for zero tangential stress on the surface of any cone with vertex at $R = 0$ is found. Means of determining φ for a given cone are not shown; it appears that the paper as printed is not complete.

D. S. Berry, England

2703. Conway, H. D., Analysis of plane stress in polar coordinates and with varying thickness, *ASME Trans.* **81**E (*J. Appl. Mech.*), 3, 437-439, Sept. 1959.

The thickness b of a plate is supposed to be a function of radial distance r. A stress function is defined and its equation found. Following the known solution for constant thickness, author finds general solution for case $b = b_0 r^{-m}$. Taking $m = 2$ he solves problem of a segment of an annulus deformed by end couples, and shows that results differ little from elementary curved-bar theory for numerical values considered.

D. S. Berry, England

2704. Goldberg, M. A., and Sadowsky, M., Stresses in an ellipsoidal rotor in a centrifugal force field, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 549-552, Dec. 1959.

An exact solution for the stress in an elastic ellipsoid rotating with constant angular velocity about an axis is obtained by super-

position of a particular solution and the general solution of the homogenous equations in terms of three potential functions. In order to satisfy the boundary conditions of zero stress, the potential functions are expressed in terms of spherical harmonics. The solution requires the inversion of a nine-by-nine matrix which depends upon the dimensions of the ellipsoid and on Piosson's ratio. This solution is tabulated for 209 special cases covering a wide range of geometrical proportions.

It is rare that an exact closed form solution in the theory of elasticity is found; the authors are to be complimented on their clear, concise, and elegant presentation of this solution.

E. H. Dill, USA

2705. Fanjat de Saint-Font, M. A., Matrix expressions of formulas in the field of strength of material, (in French), *Ann. Inst. Tech. Bât. Trav. Publics* **12,** 134, 127–146, Feb. 1959.

After a review of formulas and notations used in connection with matrices, the author, by a chain of reasoning identical with traditional methods used in materials resistance calculations, derives a matrix expression of Hooke's law and then the formulas giving the parameters of deformation in terms of the elements of reduction. It is then possible to deduce the formula of the stress vector at a point in a section. From author's summary

2706. Conway, H. D., The stresses in infinite wedges linearly tapered in width and thickness, *ASME Trans.* **81**E (*J. Appl. Mech.*), 3, 458–460 (Brief Notes), Sept. 1959.

Solutions are given for some plane stress problems of an infinite wedge linearly tapered in width and thickness, the corresponding solutions for the constant thickness cases being well known. The loadings chosen for illustrative purposes are: (a) concentrated load at end, (b) concentrated couple at end, and (c) uniform normal pressure on one face.

From author's summary

2707. John, F., On finite deformations of an elastic isotropic material, AFOSR TN 58-955 (New York Univ., Inst. of Math. Sci. 250; ASTIA AD 205 348), 68 pp., Oct. 1958.

The paper starts with a geometrical investigation as to how much a (1,1) transformation of a region D can differ from a rigid transformation if the maximum local relative extension never exceeds a given value.

The classical equations for ideal elastic isotropic material are then derived in a formulation which permits solution purely in terms of Lagrangian coordinates. If a point **M** in the constrained state goes to **M′** in the strained state and if U is the strain energy function, the equations are set up in terms of the strain tensor $P = \partial \mathbf{M}'/\partial \mathbf{M}$, and the Castigliano tensor $Q = \partial U/\partial P$. The equations of equilibrium and compatibility then reduce to $\nabla \cdot Q = 0$, $\nabla_\Lambda P = 0$.

It is then shown that the equilibrium state actually corresponds to a minimum potential energy when the displacements are prescribed on the boundary, provided that, for the deformations admitted, the tensor P is restricted to a small finite neighborhood of the unit tensor. This leads to a uniqueness theorem.

The theory is applied to the buckling problem for a rectangular plate, when two-dimensional and three-dimensional transformations are considered. L. M. Milne-Thomson, USA

2708. Ling, C.-B., On invariant perforation in an infinite strip, *ASME Trans.* **81**E (*J. Appl. Mech.*), 3, 422-431, Sept. 1959.

Paper gives an analysis of the stress distribution in a uniform strip containing two rows of equal and uniformly spaced circular holes. Each row contains an infinity of holes, which are set at equal distances from the edges, the distance being the same for each row and the two rows are symmetrically staggered. A stress function is constructed in the manner of Green [*Proc. Roy. Soc. Lond.* (*A*) **176,** 1940] and, after formidable algebraic analysis has been carried out, numerical solution of a special case is presented, under both conditions of tensile and bending load.

W. S. Hemp, England

Book—2709. Neubauer, R., Temperature and stress distribution in refractories in cylindrical reactor containers [Temperatur- und Spannungsverteilung in Ausgemauerten zylindrischen Reaktionsgefassen. Anheiz-und Abkuhlvorgange], Berlin, Springer-Verlag, 1958, 110 pp. DM 16.50. (Paperbound)

This booklet aims to give the practical technologist, who designs and develops steel containers with inner ceramic coating, for use with chemicals, a manual for easy and speedy computation of thermal stresses. The first part treats the transient heat conduction problem using Laplace transform. The boundary condition at the inner surface of the ceramic cylinder corresponds to an exponential heating or cooling process, while on the outer surface a mixed boundary condition involves an ideal heat transfer from the wall to the steel armor and an extremely high conductivity of the latter.

The treatment of the thermoelastic problem in the second part of the book is confined to the standard solution for an infinite cylinder composed of two coaxial layers with different properties. Extensive numerical tables and graphs, which comprise three quarters of the book, form the last part. They involve the temperature distribution depending on the velocity of heating or cooling, the stresses across the wall and versus the time for different velocities of heating or cooling, as well as the time maxima of hoop stress versus a heating factor (all data for wall and armor). The overpressure in the container is also taken into account.

J. Nowinski, USA

2710. Roy, M., Thermodynamic theory derived from linear elasticity (in French), *Ing.-Arch.* **28,** 277-280, Mar. 1959.

Author derives laws of elasticity by use of thermodynamics, but does not adequately clarify difference between his and classical methods. C. E. Pearson, USA

2711. Ignaczak, J., Note on the propagation of thermal stresses in a long metallic rod (in English), *Bull. Acad. Polonaise Sci.* **7,** 5, 309-314, 1959.

Generalizing an investigation by Sneddon [*Proc. Roy. Soc. Edinburgh* (*A*) **65,** 2, 121-142, 1959; AMR **12,** (1959), Rev. 6037], author obtains solutions (in integral form) of the one-dimensional coupled thermoelastic field equations appropriate to (a) an infinite and (b) a semi-infinite thin bar. The traction and the temperature at the ends of the bar are assumed to vanish permanently, while the temperature at the initial instant is an *arbitrary* function of the length-coordinate, the bar being otherwise initially undisturbed. The solution of problem (b) is valid only for sufficiently small values of the coupling parameter. No specific examples are given and the quantitative influence of the coupling effect is not discussed. W. Prager, USA

2712. Lockett, F. J., Propagation of thermal stresses in a semi-infinite medium, AFOSR TN 59–498 (Duke Univ.; ASTIA AD 215 923), 13 pp., Apr. 1959.

Adopting the equations for the coupled thermoelastic problem, i.e. retaining the inertial terms in the elastic and the rate of cubical dilatation in the heat equation, author utilizes his own more general method [*Proc. Edin. Math. Soc.* 1959] to give the formal solution of various problems relative to a half space $x_3 > 0$. The method consists in assuming that, in addition to the assigned heat sources and to the body and surface forces, there is a distribution

of concentrated forces and heat sources on the plane x_1, x_2, by the means of which the various contour conditions may be satisfied. The solutions are obtained in the form of multiple Fourier integral transforms that, in the general case, would require numerical computations. However, in a particular problem, author obtains the exact solution for the normal tension acting on the boundary, and comparison with the classical (not coupled) solution shows a maximum difference of five per cent.

T. Manacorda, Italy

2713. Parkus, H., Stresses in the cooling of a sphere (in German), *Ing.-Arch.* **28**, 251-254, Mar. 1959.

The paper discusses the thermal stresses when the surface of an ideal elastic-plastic incompressible sphere is suddenly cooled to zero. Taking the volumetric strain to be proportional to the difference of the temperatures and rejecting the dynamical effects, the displacement equation is integrated in terms of the temperature, which in turn is determined from the solution of the classical heat conduction equation. The difference of the radial and the circumferential stresses is calculated by the use of Hooke's law for the elastic range and of the Huber-Mises' yield condition for the plastic range. For small values of the initial temperature, its limit depending on the yield stress, the shear modulus and the diffusivity, the deformation is purely elastic. Beyond this there will be initially three regions, the elastic loading region, the plastic one and the elastic unloading one. Finally, the middle zone vanishes and the stress state consists of only two regions, a core of uniform constant stress surrounded by a region of variable stress. These are illustrated by graphs.

G. A. Nariboli, India

2714. Nelson, C. W., Thermal stresses owing to a hot spot in a rectangular strip, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 488-490, Dec. 1959.

From the solution to the radially symmetric problem of a hot spot in a thin infinite plate, the normal and shearing stresses are found on the lines which form the boundaries of the strip. Equal and opposite stresses are then applied to a strip not subject to temperature variation and the internal stress system is evaluated by Fourier analysis. The sum of the solutions of these two problems is the solution to the problem of the title. Author assumes no heat transfer between hot spot and strip.

D. R. Bland, England

2715. Ignaczak, J., A dynamic nucleus of thermoelastic strain in an elastic infinite space and semi-space (in English), *Bull. Acad. Polonaise Sci.* **7**, 5, 305-308, 1959.

Author uses Dirac's function as a temperature function and obtains formal solutions for the stresses in an infinite space due to a nucleus of thermoelastic strain. In the elastic semi-space, solutions for stress waves due to sudden heating of the boundary and for stresses due to sudden heating of any sub-region of the space can be obtained by using the nucleus of thermoelastic strain.

B. E. Gatewood, USA

2716. Lakshmikanth, V., and Ramakanth, J., Non-linear torsion of an orthotropic cylinder, *J. Sci. Engng. Res., India* **3**, 1, 181-186, Jan. 1959.

A second-order series solution for a right circular solid cylinder of orthotropic material in torsion is given. For a topaz cylinder, the material constants required in the solution were determined and are also given.

D. Kececioglu, USA

2717. Kosmodamianskii, A. S., An estimate of the accuracy of Saint-Venant's principles in extension of an anisotropic strip (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 9, 130-133, Sept. 1958.

The Saint-Venant principle is discussed on an example of a rectangular orthotropic plate, two opposite edges of which are subject to nonuniformly distributed symmetrical tensions. The strain distribution in the middle cross section of the plate depends on the ratio of the lengths of the edges and on the kind of orthotropy. The numeral results are given.

Z. Kaczkowski, Poland

2718. Verma, P. D. S., Hypo-elastic strain in a rotating shaft and a spherical shell, Proc. 2nd Congr. Theor. Appl. Mech., New Delhi, India; Indian Soc. Theor. Appl. Mech., Indian Inst. Technol., Kharagpur, 1956, 99-110.

According to the hypothesis of the hypo-elastic behavior of incompressible isotropic materials, as given by Truesdell, Noll, Seth and others, the author investigates the question: whether, for bodies in equilibrium, a linear relation between the rate of stress tensor and the rate of strain velocities will give similar results as a linear stress-strain relation, used by Seth. In a previous paper the author explained that the particular form of the stress-strain relations has no influence on the flexure problem. In this paper he shows that also in the problem of a rotating hollow shaft and of a spherical shell the results are of similar form for both stress-strain assumptions.

H. Neuber, Germany

Viscoelasticity

(See also Revs. 2718, 2781, 2793, 2806, 2807, 2816, 2882)

2719. Goulard, Madeline, Extension of a variational theorem for creep to curvilinear coordinates, Purdue Univ., School of Aero. Engng. S-58-1, 9 pp., Aug. 1958.

Variational theorem for creep established by Sanders, McComb and Schlechte, AMR **10**(1957), Rev. 3956, and presented in Cartesian coordinates is restated by author in general curvilinear coordinates.

H. Parkus, Austria

2720. Tordion, G. V., Creep of an elastic belt on a pulley, *ASME Trans.* **81**E (*J. Appl. Mech.*), 3, 451-452(Brief Notes), Sept. 1959.

A new, more general, relation between belt tensions of an elastic belt on a pulley as well as the expressions for the creep velocity distribution and creep losses are obtained, using the theory of the ideal compressible fluid flow.

From author's summary

2721. May, W. D., Morris, E. L., and Atack, D., Rolling friction of a hard cylinder over a viscoelastic material, *J. Appl. Phys.* **30**, 11, 1713-1724, Nov. 1959.

Very simplified analysis is used to obtain approximation to rolling friction force in cases where bulk properties of viscoelastic material may be represented by a single simple or coupled Maxwell model. These results are compared with those of more extensive caluclations using methods of AMR **10**(1957), Rev. 3558, and agreement in character is shown to be good. Methods are extended to materials having a continuous spectrum of relaxation times, and variation of rolling friction force with cylinder velocity is shown to follow closely the shape of the spectrum. This is suggested as basis of experimental method of obtaining an approximation to the spectrum shape.

K. H. Griffin, England

2722. Naghdi, P. M., and Orthwein, W. C., Response of shallow viscoelastic spherical shells to time-dependent axisymmetric loads, AFOSR TN 58-993 (Univ. Mich. Res. Inst. TN 4; ASTIA AD 205 905), 24 pp., Nov. 1958.

This paper contains an excellent discussion of the linear theory of the responding unlimited shallow viscoelastic spherical shells and of shallow viscoelastic shell segments to arbitrary time-dependent axisymetric loads. The medium is assumed homogeneous and isotropic. Authors use the recent work on vibrations of thin shallow elastic shells by E. Reissner who, by utilizing the linear differential equations due to Marguerre, has shown that for transverse vibrations of shallow shells the longitudinal inertia terms may be omitted. Authors eliminate time dependence by using Laplace transform and employ the Hankel transform too.

The solutions for a shallow elastic shell and for the case of a flat plate are also given as by-products of the general solutions, and comparison is made with known results. Explicit results in integral form are deduced for viscoelastic shells under instantaneous pulse loading uniformly distributed about and concentrated at the apex, and are particularized to the cases of incompressible Maxwell and Kelvin solids. The integrals converge rapidly. An example is given of spherical shell with a pulse loading uniformly distributed about the apex. The plots of the axial displacement are shown for the incompressible Maxwell and Kelvin solids. Results are presented in three figures. Authors show that under intantaneous loading, the shell medium for the Maxwell solid will assume a permanent deformation; no such effect is present in the solutions for the Kelvin solid.

S. Sarkadi Szabo, Hungary

2723. Hoff, N. J., Jahsman, W. E., and Nachbar, W., A study of creep collapse of a long circular cylindrical shell under uniform external pressure, *J. Aero/Space Sci.* **26,** 10, 663-669, Oct. 1959.

Adopting a Lagrangian form of reference, the authors derive equations for the motion of an infinitely long sandwich cylinder under uniform external pressure permitting only secondary creep deformations in a doubly symmetrical mode. They obtain a solution by assuming the cross section initially and thereafter quasielliptic with one time-dependent parameter adjusted to approximately satisfy the equations on an integrated average over the cross section. Calculations for a cubic creep law predict collapse of the cylinder after a finite time which depends on initial deformation as well as pressure—the smaller the initial deformation the more sensitive the collapse time. Interestingly, the result has the same form as found by Hoff [AMR **7**,(1954), Rev. 2444] for a column.

R. W. Leonard, USA

2724. Stauffer, W., and Keller, A., Application of Stussi's theory for fatigue to the results from creep rupture tests (in German), *Arch. Eisenbüttenw.* **29,** 7, 411-414, July 1958.

Experimental results from creep rupture tests are presented for one unalloyed and seven alloyed steels. Some of the latter were high temperature steels.

Authors use Stussi's [AMR **10**(1957), Rev. 3645] equations for fatigue and show that similar equations can be developed for creep rupture test. Authors further state that constants for creep rupture equations can be determined from fatigue tests. This means that relatively short fatigue tests can be carried out and the resistance to creep predicted for test times of 100,000 hours. Agreement between theory and experiment is exceptional.

The theory can also be used to develop lines for one or two per cent extension. Authors conclude by showing that theoretical prediction agrees with experimental results much better than the presently employed DVM creep limit.

J. E. Stallmeyer, USA

Plasticity

(See also Revs. 2713, 2718, 2743, 2785)

2725. Phillips, A., The neutral axis in plastic bending of beams, *Proc. Amer. Soc. Civ. Engrs.* **85,** EM 4 (*J. Engng. Mech. Div.*), 65-76, Oct. 1959.

On the basis of the elementary theory of bending of beams in plasticity a simple graphic method is outlined to find the elastic-plastic boundaries corresponding to a given position of the neutral axis. Author discusses the motion of the neutral axis with increasing curvature in plasticity. A cross section with only one axis of symmetry which lies in the plane of the external forces is assumed and also a linear strain-hardening of the material. The form of cross section is characterized by two decisive curves beginning at the lower and higher fibers of the cross section. With the aid of these curves the position of the elastic-plastic boundaries can be found graphically. Finally, formulas are developed expressing the rate of motion of the neutral axis as a function of the curvature.

L. Foppl, Germany

2726. Zhukovskii, V. S., Stress distribution in notched bars for elasto-plastic deformations (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 7, 132–136, July 1957.

Author considers notched bars of rectangular and solid circular cross sections. Author's computation method is based on the improvement of G. V. Uzhik's solution by taking into account work-hardening in the plastic range. Neuber's equations are used in elastic range. The criterion for plasticity was maximum shearing stress. Form of notches was always hyperbolic, and in performed tests deformations were measured between marked points spaced at 0.1 mm on the base, taking microphotographs with a 120 multiplication. Maximal stress in the root of notches was determined through comparison of the measured maximal deformation of notched specimens and one without any notch. For diameters of 20–24 mm, strain state in circular rods was equal to that in rectangular bars.

A comparison of results obtained by author's method in cases of flat deformation with solutions of Uzhik and B. P. Kishkin shows certain differences, and author's result for stress component normal to the plane of flat specimen exhibits a sudden change of direction due to the omitted volume deformation in plasticity. In axially symmetric case the differences between solutions of author and those of Uzhik and of A. N. Grubin are less because the effect of the change in the radius of curvature occurring at the bottom of the notch taken into account in Grubin's method is not too big.

B. O. Kuzmanovic, Africa

2727. Ershov, L. V., and Ivlev, D. D., Elasto-plastic state of stress of a hollow thick-walled tore, subjected to internal pressure (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 7, 129-131, July 1957.

Paper considers a tore formed through the rotation of a thick-walled ring about an axis situated in its plane. The distance from the ring center to the rotation axis is assumed sufficiently large as to make negligible the powers of the inverse of this distance with respect to unity.

Proceeding from the equilibrium equations in stresses expressed in polar coordinates for a cylinder, with corrections equivalent to certain extraneous forces which compensate the effect produced by the additional curvature due to the tore shape, and subtracting the known solutions corresponding to the elasto-plastic problem of the ring, author obtains two linearized equations for the correction stresses. Further, assuming that the normal plastic correction stresses are equal, and that the elastic ones give an incompressi-

ble state, he solves the boundary problem for the internal pressure. The critical stress and pressure are also obtained.

M. M. Misicu, Roumania

2728. Paul, B., Carrying capacity of elastic-plastic shells with various end conditions, under hydrostatic compression, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 553–560, Dec. 1959.

Paper, an extension of AMR **12**(1959), Rev. 5469, considers the influence of the beam-column effect on carrying capacity of cylindrical shells with clamped edges, simply supported edges, and a combination thereof. It is shown that there are two modes of failure depending on length of shell. Axisymmetic, fully plastic modes of deformation are assumed.

Calculated results and conclusions useful in design are presented. A statement is made on spacing of rigid reinforcing rings, and a rule-of-thumb is given as "long shells will tend to buckle elastically; short shells will tend to fail by yielding."

R. Schmidt, USA

2729. Nakanishi, F., and Sato, Y., Three shear theory of plasticity, *Bull. JSME* **2**, 6, 257–264, May 1959.

Authors claim having advanced a new theory of plasticity which they elaborate on in a rather obscure way. They state that their theory should be able to account for the stress relation between plastic simple tension and plastic pure shear, cover the duration from deviation from elasticity in hysteresis loops due to plasticity and the relation between yielding of mild steel and the plastic deformation beyond the yieldpoint. Instead of using the values of the principal stresses σ_1, σ_2, σ_3, they split the total state of stress into the three principal states of pure shears, neglecting to deal with the deviational parts, and they assume, when the principal directions of stress and plastic strain stay in coincidence, that the inner resistance of the material under monotonically increased stresses increases in the planes of principal shears by the same amount R. When the direction of straining is reversed, in unloading, they assume that the reversed strain is elastic within the range R. No word can be found in the paper about incremental states of flow or rates (velocities) of flow. Putting under pure shear the maximum shear stress $\tau_{max} = 2R$ and under simple tension $\tau'_{max} = (7/4)\,R$, they arrive at the conclusion that their ratio equals 7/8. Some tests with small brass tubes are reported under combined stress that conformed "closely" with their "three shear theory of plasticity."

A. Nadai, USA

2730. Yoshimura, Y., Meta-theory of mechanics of continua subject to deformations of arbitrary magnitudes (Duality of definitions of strain, strain increment and stress for elastic and plastic finite deformations), Aero. Res. Inst., Tokyo Univ., Rep. 343, 23 pp., May 1959.

Author states that finite strains should be defined essentially in the customary way for elastic behavior but that plastic strains should be taken as the integral of strain increments based on the current state. Expressions are written in terms of the metric tensors and unit vectors in the deformed and undeformed state. The advantage of defining plastic strain in this way rather than working with plastic strain increments alone is not clear to this reviewer except insofar as the importance of strain history is emphasized.

D. C. Drucker, USA

2731. Ketter, R. L., Plastic design of pinned-base gable frames, *Welding Res. Counc. Bull.* no. 48, 28 pp., Mar. 1959.

In this paper the assumptions of the simple plastic theory and a short description of the various methods whereby solutions to problems in plastic analysis can be obtained are first presented.

The mechanism method is then used to solve the single-span gable frame problem, and the results are given in the form of design charts.

This is followed by an attempted extension of the procedures used for the single-span case to the multiple-span problem. The difficulties of using such an approach are discussed.

Next, a different approach to the plastic analysis and design of multiple-span structures is presented. It is based on the concept of dividing the structure into substructures (single-span structures) for the purposes of analysis.

The equations governing the solution of each of these substructures are obtained and design charts are presented.

To aid in the determination of the "least-weight" design, the relationship between the fully plastic moment value and the unit weight of rolled wide-flange shapes is considered.

Finally, four design problems, typical of those found in practice, are solved to illustrate the methods developed.

From author's summary by K. Angervo, Finland

2732. Charnes, A., Lemke, C. E., and Zienkiewicz, O. C., Virtual work, linear programming and plastic limit analysis, *Proc. Roy. Soc. Lond.* (*A*) **251**, 1264, 110–116, May 1959.

Using matrix notation and the principle of virtual work, authors establish for frame structures a representation of the "static" and "kinematic" principles of plastic structure theory as dual linear programming problems and prove the existence of collapse mechanisms. For trusses similar results have been obtained earlier.

It is interesting to note that many of the tools worked out by the authors in order to establish their results for plastic structures are almost identical to those used in recent matrix analysis works on elastic structures. This is the case for the parametric form of static equations, for the manner of introducing the compatibility conditions and for the representation as a nonscalar network, see for instance Langefors [AMR **12**(1959), Rev. 6127].

B. Langefors, Sweden

2733. Kriz, L. B., Ultimate strength criteria for reinforced concrete, *Proc. Amer. Soc. Civ. Engrs.* **85,** EM 3 (*J. Engng. Mech. Div.*), 95–110, July 1959.

Paper presents theoretical consideration for homogeneous beams, reinforced-concrete beams, and eccentrically loaded reinforced-concrete columns. Ultimate strength of reinforced-concrete members is derived by analytically determining extreme compression edge strains, which lead to determination of maximum loads on structural members. Stress-strain relationship of concrete in flexure was found experimentally by testing twenty plain rectangular concrete specimens under eccentric loads. Loading device was arranged in such a way that one edge was under no strain. Theoretical vaules of ultimate moments were determined from experimental stress-strain relationships. Equations in 1956 ACI building code regarding ultimate strength design are confirmed by experimental and theoretical results of this paper.

B. G. Eppes, USA

2734. Perrone, N., and Hodge, P. G., Jr., Strain-hardening solutions to plate problems, *ASME Trans.* **81**E (*J. Appl. Mech.*), 2, 276–284, June 1959.

Paper is concerned with the application of the kinematic hardening theory [W. Prager, *J. Appl. Mech.* **23**, 1956, 493–496] to plane stress problem. Two ways of formulation of flow laws for plates, namely those of direct and complete hardening, are discussed. In the direct hardening the strain rate field for plates is two-dimensional, while in the second case the strain rate field is three-dimensional and satisfies the incompressibility condition. Two corresponding sets of flow laws are derived and integrated for circular plates in the case of an initially Tresca material. Moments and deflections obtained [using the two mentioned methods] are compared for an annular plate and some other boundary conditions. Virtually no qualitative difference is evident be-

tween the complete and direct hardening solutions in those cases which seem to be valid for plates in general. Substantial differences between the kinematic and isotropic hardening solutions are also pointed out. A. Sawczuk, Poland

2735. Clevuot, C., and Ziegler, H., On hardening rules (in German), *Ing.-Arch.* **28,** 13–26, Mar. 1959.

Consequences of various hardening rules for rigid/plastic solids are worked out in some detail for a material element in special states of distortion, for instance plane strain and plane stress. Attention is focused on Mises or Tresca-type yield surfaces which merely translate in 9-dimensional stress space with continued straining, without change in shape. The various hardening rules (Prager, Hodge, Ziegler) differ in regard to the postulated dependence of this translation on the strain-increment and current stress. For the associated flow rule it is always assumed that there is a plastic potential coinciding with the yield function.

Such hardening rules are expressly designed to simulate the Bauschinger effect in metal polycrystals. This effect is, of course, most evident when the plastic strain in reversed loading is only of elastic order of magniture, particularly when many crystals in the aggregate have not yet become plastically stressed in the reverse direction. With continued reversed strain the effect rapidly diminishes and even vanishes in certain pure metals (though not in certain alloys). Moreover, in contrast to basic plastic behavior, the effect is modifiable by a mild annealing. Consequently it appears to the reviewer that the Bauschinger effect is fundamentally different from the kind of behavior for which rigid/plastic theory is appropriate, and that a phenomenological theory is unlikely to be successful, even in general trends, unless (1) it incorporates an elastic component of strain strongly dependent on strain-history, and (2) it relaxes the severe restrictions that the direction of the plastic strain-increment shall not only depend solely on the current stress but shall be normal to the current yield surface. Up to the present the only theoretical and experimental support for (2) is under conditions of straining such that the Bauschinger effect is absent.

R. Hill, England

2736. Zhukov, A. M., Some features of the neutral loading curve (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 8, 32–40, Aug. 1958.

Paper describes experiments carried out on "neutral" loading tests. Aluminum tubes were subjected to internal pressure and axial tension and steel tubes to combined tension and torsion. It is concluded: (a) Elastic behavior (Young's modulus) depends upon previous plastic deformations. (b) Curve of neutral loading (plastic potential) does not coincide with the ellipse of the theory of Huber-von Mises. (c) Theory of unloading is to be corrected.

O. Halasz, Hungary

Rods, Beams and Strings

(See also Revs. 2716, 2726, 2779, 2788, 2789, 2790, 2791, 2793, 2794, 2808, 2829, 2839, 2869, 2873, 2883)

2737. Keller, J. B., Large amplitude motion of a string, *Amer. J. Phys.* **27,** 8, 584–586, Nov. 1959.

Using Lagrangian coordinates to represent the position of the string and assuming a special stress-strain law for the string material author derives the equation of motion of the string without making any approximations regarding the amplitude or mode of vibration that are usually made to study such motion. It is found that the equation of motion in each case is the usual linear wave equation, in case the elastic constant a and the density ρ of the string material are not functions of position, s. Further it is shown that the special stress-strain law assumed is the only one for which a purely transverse motion of a string is possible.

In the opinion of the reviewer author should have discussed also the case where a and ρ are functions of s.

A. M. Sengupta, India

2738. Platt, M. M., Klein, W. G., and Hamburger, W. J., Mechanics of elastic performance of textile materials, Part 14: Some aspects of bending rigidity of singles yarn, *Text. Res. J.* **29,** 8, 611–627, Aug. 1959.

Theoretical analyses are given of the effects of fiber properties and yarn structure on singles-yarn bending rigidity, assuming the fibers to be elastically isotropic and to exhibit linear stress-strain behavior. The two extreme cases of complete freedom and of no freedom of relative fiber motion are analyzed. The effects on yarn rigidity of fiber dimensions, fiber stiffness, torsional-to-bending rigidity ratio, yarn density, size, twist, fiber clustering, and prior relaxation treatments are analytically investigated.

No comparison with experiment is made.

From authors' summary by D. J. Montgomery, USA

2739. Book—Vlasov, V. Z., Thin-walled elastic bars [Tonkostennie uprugie sterzhni], Moscow, State Publishing House for Physico-Mathematical Literature, 1959, 568 pp. 20.35 rubles.

Linear differential equations based upon infinitesimal deformations are derived for the equilibrium of thin-walled bars of open profile. Equations pertaining to (a) arbitrary coordinates, and (b) lines of curvature, are presented. These equations include bending, torsion, and axial load effects. General expressions for location of the shear center of an open section are derived. The method of initial functions, previously developed by the author for plates and shells, is extended to include the case of thin-walled open sections subject to pure torsion. This technique is then applied to numerous boundary-value problems of open-profile bars. It appears that the method, exposed here for the first time, offers certain advantages in the elastic analysis of the torsion of such sections, particularly in the case of restrained warping of certain cross sections.

The linear elastic deformations of open thin-walled sections with transverse bracing are considered in detail for many boundary-value problems. For example, the stiffening effects of transverse diaphragms in thin channels is evaluated by considering the elasticity of these elements and matching boundary conditions at the junctions of the channel and diaphragms. Tedious calculations are avoided by introduction of the Stieltjes integral.

The elastic stability of axially compressed thin-walled open sections is considered on the basis of infinitesimal deformations. The treatment permits a consideration of loads applied at an arbitrary point in the cross section. Results of these analyses applied to thin hat-sections are shown to be in good agreement with tests carried out by the author. The predictions of the conventional Euler theory are shown to greatly overestimate the buckling loads for such cases. This theory for axial compression is later extended to include the simultaneous effect of bending and torsional loads. The effect of transverse bracing on stability characteristics is investigated by small-deflection theory.

Natural frequencies of bending-torsional vibrations of thin-walled bars may be determined from general equations including the effects of warping of cross sections. Examples are presented to show that in certain cases these equations may be solved by separation of variables. The problem of vibrations of suspension bridges is considered in detail.

The small deformations of thin-walled open sections subject to varying temperatures over their depth are considered and equations based solely upon membrane theory presented. Finally, the defor-

mations of spatially curved bars of open section are considered. Differential equations of equilibrium are derived on the assumption of small curvatures of the axes of the cross sections. The problem of an I-section shaped as a helix around a circular cylinder is considered in detail. The book concludes with a listing of approximately 300 references. W. A. Nash, USA

2740. Rivello, R. M., The yield strength of beams in pure bending, *J. Aero/Space Sci.* **26,** 6, 393–394 (Readers' Forum), June 1959.

2741. Krishnan, S., and Shetty, K. V., On the optimum design of an I-section beam, *J. Aero/Space Sci.* **26,** 9, 599–600 (Readers' Forum), Sept. 1959.

Optimum design of any thin-walled beam is generally based on the condition of simultaneous failure in local buckling of the compression element and by direct stress due to bending. A method of determining the optimum dimensions for an I-section beam by minimization of the weight subject to the above conditions of failure is described and the results are compared with those obtained by Shanley and Micks by their well-known structural-index method for a typical example. From authors' summary

2742. Simon, A. W., Theory of beams composed of two elastic materials, *Amer. J. Phys.* **27,** 7, 500–502, Oct. 1959.

The theory involved in locating the neutral axis of a beam composed of two elastic materials (composite beam) is given. It is shown that the resulting flexural rigidity of such a beam is equal to the sum of the flexural rigidities of its parts. With these two factors, the tensile strain, tensile stress, slope and deflection of the beam can be calculated from the usual formula. The shear stress is also calculated.

From author's summary by C. Massonnet, Belgium

2743. Hodge, P. G., Jr., and Sankaranarayanan, R., The determination of safe loads of beams subjected to combined twisting and biaxial bending moments, *ASME Trans.* **81**E (*J. Appl. Mech.*), 3, 442–447, Sept. 1959.

Using the lower-bound theorem of limit analysis, a yield criterion is obtained in terms of the stress resultants for a beam, subjected to combined twisting and biaxial bending moments. Based on a piecewise linear approximate yield condition, the "collapse load" is determined for a right-angle bent, subjected to a load in an arbitrary direction applied to the mid-point of one leg. Such a collapse load, which is a "safe load" for the beam, is plotted as a function of a suitable parameter.

A. W. Coutris, USA

2744. Robertson, R. G., The three-span articulated beam, *Proc. Instn. Civ. Engrs.* **13,** 467–476, Aug. 1959.

A method is described for finding the correct span proportions, depth, and haunch sizes (when necessary) for a three-span beam which has a suspended (drop-in) section in the center span.

The method is illustrated by a design chart and a worked example for a prestressed-concrete beam, but the method applies equally (and with even greater comparative economy) to normal reinforced-concrete designs.

Finally the worked example is compared to a previous design for a uniform continuous beam and for three simple spans.

From author's summary

2745. Sisto, F., Torsion of a prismatical bar whose section is a crescent, *Trans. ASME* **81**A (*J. Engng. Power*), 4, 428–432, Oct. 1959.

Relative to use in evaluating torsional characteristics of compression and turbine blades in axial-flow turbomachines, the Saint-Venant torsion problem is solved for the stated section by conformally mapping it on an infinite strip and subsequent determination of the stress function as a Fourier integral. Therewith the torsion constant results as a triple integral. Analytic integration yields expression involving single integrals amenable to numerical integration. A series-form approximate expression for small camber is derived. Numerical values of the torsion constant are given for six specifically-dimensioned crescents. An expression is given for the maximum shear stress: in terms of single-fold integrals, amenable to numerical integrations.

The results of this paper complement results obtained earlier by Uflyand [*Doklady Akad. Nauk SSSR (N.S.)* **68,** pp. 17–20, 1949] for the same section. The present results are stated as of particular value in application to turbomachine blades.

T. J. Higgins, USA

2746. Zaslavsky, A., A steel beam on immovable supports, *Bull. Res. Council Israel* **6**C, 4, 235–239, Dec. 1958.

In a simply supported beam one support is assumed to be movable. The movability of the support prevents the appearance of additional stresses due to axial forces induced by temperature, second-order deformations, etc.; also no horizontal forces are transmitted to the supporting columns, etc.

This paper deal with a single-span steel beam supported by two absolutely immovable supports under normal loading. It is shown that a considerable *compressive* axial force is induced in the beam, and the stresses are calculated.

From author's summary

2747. Gospodnetic, D., Deflection curve of a simply supported beam, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 675–676 (Brief Notes), Dec. 1959.

2748. Blake, A., Deflection of a thick ring in diametral compression by test and by strength-of-materials theory, *ASME Trans.* **81**E (*J. Appl. Mech.*), 2, 294–295 (Brief Notes), June 1959.

Experimental and theoretical deflection studies are briefly described for several steel rings, of uniform rectangular cross section, compressed by two forces along a diameter and having D/d ratios ranging from 1.3 to 1.9. The calculations are based on the principle of Castigliano and expressions for strain energy due to bending, normal, and shear stresses. Discrepancies between the theoretical estimate and the tests are shown.

From author's summary

Plates, Shells and Membranes

(See also Revs. 2707, 2717, 2722, 2723, 2728, 2783, 2785, 2786, 2794, 2795, 2796, 2797, 2798, 2800, 2801, 2802, 2807, 2821, 2847, 2884)

Book—2749. Novozhilov, V. V., The theory of thin shells, 2nd ed. (Translated from the Russian by P. G. Lowe), Groningen, Netherlands, P. Noordhoff, Ltd., 1959, xvi + 376 pp. $8.75. (Paperbound)

This splendid translation into English now makes available a very unique book published in 1951 [AMR **9** (1956), Rev. 706]. The treatise is devoted entirely to the analysis of stresses and deformations in thin elastic shells. Only the linear problem is considered, i.e. the displacements are assumed to be small in comparison with the thickness of the shell.

The book is divided into four chapters. The first presents an exposition of the general theory of thin elastic shells. Herein lies the uniqueness of this treatment. Using generalized curvilinear coordinates, the author presents the equilibrium equations in terms of "complex" stress resultants. These equations are three in number and are equivalent to the six equations obtained

by direct equilibrium considerations. For the case when the components of surface loading are zero these equations assume a particularly simple form. In the general nonhomogeneous problem the simple form is still reasonably accurate if the derivatives of the loading components with respect to the curvilinear coordinates are of smaller order than the loading components themselves.

Chapter two is concerned with the membrane theory of shells. The basic equations are derived as special cases of the above-mentioned equations. Membrane analyses of spherical and cylindrical shells are carried out for a variety of loadings and boundary conditions. Chapter three treats cylindrical shells, oval shells, cylindrical panels reinforced by ribs and cylindrical shells with abruptly changing radius of curvature. The concluding chapter is concerned with shells of revolution and various approximate methods for integrating the differential equations of equilibrium expressed in terms of the "complex" stress resultants.

The various types of problems presented as illustrations indicate that the introduction of "complex" quantities results in comparatively simple equations for certain shell geometries. It would appear that further exploitation of this approach would be in order.

W. A. Nash, USA

Book—2750. Girkmann, K., Plates and shells—introduction to the elasto-statics of thin slabs, plates, shells and prismatic structures [Flachentragwerke], 5th ed., Wien, Springer-Verlag, 1959, xxxi + 632 pp. $17.15.

A notable treatise planned to encourage practising structural engineers to make fuller use of elasticity theory, hence achieving economy and elegance in design. Mathematical standard required for perusal is similar to that for treatises by Prescott, Timoshenko, etc.; emphasis is on methods and results of solution to problems of frequent occurrence in steel and reinforced-concrete construction. Following a short introductory chapter, text treats, with characteristic thoroughness, "two-dimensional support structures" (Flächentragwerke) comprising thin slabs and flat plates of various shapes and boundary conditions, shells (membrane and general solutions), prismatic or folding structures. Orthotropic systems, stability, etc., are discussed. New, fifth, edition includes lengthy appendix on E. Reissner's thin plate theory. Commendable feature is addition of author index. Text proper is prefaced by annotated bibliography (120 entries) indicating advances since last edition, and in addition to already very extensive bibliographies appended to each chapter.

Publication of new edition so soon after the 4th [AMR **11** (1958), Rev. 3054] indicates high regard for this masterly contribution to literature on applied elasticity. A worthy addition to every technical library.

F. A. Gerard, Canada

2751. Gallelly, G. D., and Radok, J. R. M., On the accuracy of some shell solutions, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 577–583, Dec. 1959.

R. B. Dingle's method for finding asymptotic solutions of ordinary differential equations of a type such as occur in the bending theory of thin shells of revolution is presented in outline. This method leads to the same results as R. E. Langer's method recently used for problems of this kind, and permits a simple analytical and less formal interpretation of the asymptotic treatment of such equations. A comparison is given of edge influence coefficients due to bending loads, obtained by use of these asymptotic solutions and numerical integration of the equilibrium equations, respectively. The particular shells investigated are of the open-crown, ellipsoidal, and negative-curvature toroidal types. The results indicate that the agreement between these solutions is satisfactory. In the presence of uniform pressure, the use of the membrane solutions for the determination of the particular integrals appears to lead to acceptable results in the case of ellipsoidal shells. However, in the case of toroidal shells, the membrane and the numerical solutions disagree significantly.

From authors' summary by M. G. Salvadori, USA

2752. Flugge, W., and Conrad, D. A., A note on the calculation of shallow shells, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 683–685 (Brief Notes), Dec. 1959.

Authors solve the differential equations of the problem by Fourier series. Solution is divided into two parts—the flat plate portion and the portion due to curvature in the shell. Authors claim chief advantage of method lies in better convergence. Approximation that projections of lines of principle curvature are rectangular is used and solution is limited to cases of constant curvature. Method is illustrated by application to shallow sphere, cylinder, and hyperboloid subjected to a single concentrated load at the center.

R. E. Miller, USA

2753. Schmidt, R., A series solution for ellipsoidal shells, *ASME Trans.* **81**E (*J. Appl. Mech.*), 3, 463–464 (Brief Notes), Sept. 1959.

A series solution of Meissner's equations for ellipsoidal shells of revolution subjected to axisymmetrical load is obtained for the case of uniform thickness. The edge moments and forces are presented for a particular shell with clamped edge.

From author's summary

2754. Zerna, W., The calculation of the membrane stresses in doubly curved shells of arbitrary plan (in German), *Ing.-Arch.* **28**, 363–365, Mar. 1959.

Author shows in his paper that it is possible to treat mathematically the membrane stress state of a double-curved shell, even if the plan view of the shell is arbitrary. By applying vector calculation and starting from the general equilibrium condition of the membrane theory, three scalar equations are derived, from which circumferential normal force N_ϕ and shear force T are eliminated by differentiation. Thus the differential equation of second order is obtained for normal force N_x acting in the longitudinal direction of the shell. If N_x and N_ϕ are known at the edges of the shell, an approximate solution can be derived for the above-mentioned differential equation.

E. Niskanen, Finland

2755. Eberle, E., Stresses in cylindrical shells of finite length, *Sulzer Tech. Rev.* **41**, 1, 71–80, 1959.

The problem dealt with here is encountered in many fields of engineering, including the construction of reactors and nuclear power plants. Precisely in these latter applications, a knowledge of the mechanical stresses involved is of the greatest importance if absolute safety is to be combined as far as possible with economy. Special attention has been paid to the investigation of comparatively short cylinders in which edge effects make themselves felt along the whole length of the shell. It is shown that this does not involve any restriction to a narrow field of application, for owing to a typical property of shells the results can easily be transferred to cylinders of any length. The graphical presentation of the results enables the designer to form a quick idea of the influence of various edge effects.

From author's summary

2756. Grigolyuk, E. I., Finite deflections of three-layered shells with a hard core (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 1, 26–34, Jan. 1958.

Basic relations for sandwich shells are discussed taking into account the bending rigidity of the faces and of the core, the transverse deformation of the core, and considering the deflections as being finite. The materials of the faces and the core are assumed elastic and anisotropic. It is assumed that the displace-

ments vary linearaly through the thickness. Using variational methods, the basic differential equations of the problem and the corresponding boundary conditions are derived. This system is reduced to four equations in terms of the normal deflection, two components of the rotation of the lines normal to the middle surface, and a stress function. M. P. Bieniek, USA

2757. Yu, Y.-Y., On the Donnell equations and Donnell-type equations of thin cylindrical shells, Proc. Third U. S. Nat. Congr. Appl. Mech., June 1958; Amer. Soc. Mech. Engrs., 1958, 479–487.

After reviewing previous work on Donnell-type shell equations, author derives a new set. No explanation is given for the choice of which of a certain class of terms are retained and which are dropped. F. L. Dimaggio, USA

2758. Ivanov, V. S., On the problem of a static elastic circular cylindrical shell with initial deflection, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **22,** 5, 965–971, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Subject and method of treatment are closely related to those of the problems of elastic stability of cylindrical shells, including the procedure of minimization of certain functions from the point of view of the mathematical apparatus involved and the phenomenon of "snap-through" from the point of view of accompanying physical effects. To be more specific a few lines are added from the summary given by the author: contrary to some earlier publications to the title problem his "paper considers the case of a shell, under the action of uniformly distributed pressure, assuming deflectional equilibrium shapes characterized by a number of waves *differing from that of the cyclical initial deflection.* The solution of the problem is obtained in a nonlinear treatment for loosely supported short cylindrical shells."

I. Malkin, USA

2759. Mishonov, M., On the theory of shallow shells, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **22,** 5, 972–979, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Paper is of interest to mathematically trained engineers working in certain special domains of the title problem. It is based upon results derived by the well-known Russian engineer-scientist V. Z. Vlasov. Author starts from Vlasov's form of the system of differential equations for the case of a shallow shell under normal loading and he indicates the special type of shell curvatures which permits convenient application. Furthermore he generalizes Vlasov's system just mentioned to the case of shallow shells under arbitrary loading. The latter system of equations is then applied to the case of uniformly distributed tangential loading and to that of a shell of constant curvature under arbitrary tangential loading. The second of these two problems has been studied already by O. D. Oniashvili, for certain special conditions. Mishonov solves it by means of double trigonometric series. Explicit results are obtained in each of the two problems just indicated. The presentation is clear and easily readable.

I. Malkin, USA

2760. Ambartsumyan, S. A., On the analysis of two-layered orthotropic shells (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 7, 57–64, July 1957.

The following assumptions are introduced: (1) In each layer of the shell the linear element normal to the coordinate surface does not change its length after deformation, (2) In determining the transverse shear strains it is assumed that the transverse shear stresses do not differ from the corresponding stresses found on the basis of the hypothesis of an undeformable normal, given for the shell as a whole. The basic equations are derived and an example is worked out. G. Herrmann, USA

2761. Csonka, P., Method for approximate calculation of shells curved in two directions, Proc. 3rd Congr. Theor. Appl. Mech., Bangalore, India; Indian Soc. Theor. Appl. Mech., Indian Inst. Technol., Kharagpur, 1957, 49–58.

Author presents a method of numerical approximation for the membrane stresses in shells curved in two directions and loaded by distributed vertical forces. With the assumption that there is no resistance against forces acting perpendicular to the planes of the edge arches a stress function is used as a sum of assumed functions exactly satisfying the boundary conditions. The constant coefficients of these functions are treated as indefinite parameters in the equation of the middle surface of the shell by aid of the procedure of Galerkin. A numerical example is given for a parabolic shell. H. Neuber, Germany

2762. Wintergerst, E., and Lintz, H., Properties and applications of metal diaphragms (in German), *Regelungstech.* **7,** 5, 160–165, May 1959.

Introductory remarks are followed by a survey of the methods of calculation and also of the properties and applications of metal diaphragms. A short reference is made to the well-known formulas for calculating plain metal diaphragms. However, the methods of approximate calculation of concentrically undulated diaphragms, which have been developed only recently, are dealt with more fully. The article contains a brief report on empirically found values and examples of the application of metal diaphragms in measuring and control devices, with particular consideration of the problem of safety at excess pressures.

From authors' summary

2763. Fletcher, H. J., Bending of isosceles right triangular plates, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 625–628, Dec. 1959.

A former paper of the author [AMR **8**(1955), Rev. 3690] dealt with bending of thin rectangular plates under arbitrary loads and all combinations of standard uniform edge conditions. The present paper shows that the solutions for square plates can be easily extended to those of isoceles right triangular plates using an antisymmetric load or superimposing a concentrated diagonal load. In this manner 15 of the possible 18 problems of edge conditions can be solved. Series expansions of trigonometric and hyperbolic functions are used. A numerical solution of an example with constant load is given. E. Monch, Germany

2764. Bodine, R. Y., The fundamental frequency of a thin, flat, circular plate simply supported along a circle of arbitrary radius, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 666–668, Dec. 1959.

The fundamental transverse frequency is determined for a thin, flat, circular plate simply supported along a circle of arbitrary radius. It is shown that there are three support locations which coincide with "classical" plate solutions. The dimensionless frequency is plotted against the ratio of the support radius and outer-edge radius, showing the frequency variation with support location. The maximum frequency occurs when the support is located at the diameter of the first nodal circle of a free-edge plate.

From author's summary by M. S. Weinstein, USA

2765. Thorkildsen, R. L., and Hoppmann, W. H., II, Flexure of nonhomogeneous cylindrically aeolotropic plate, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 669–672 (Brief Notes), Dec. 1959.

A method is presented for determining the deflection of a circular plate in which the elastic constants are cylindrically aeolotropic but vary along the radius.

From authors' summary

2766. Bradley, W. A., Laterally loaded thin flat plates, *Proc. Amer. Soc. Civ. Engrs.* **85,** EM 4 (*J. Engng. Mech. Div.*), 77–107, Oct. 1959.

Author gives results of research carried out on laterally loaded thin plates by the use of Moire photographic interference technique and by finite differences method. The procedures followed and the results arrived at are discussed and possible errors in the Moire method indicated. This method appears to be particularly applicable to the solution of problems connected with plates of unusual shapes and with boundary conditions which are difficult to formulate. Thus this technique by itself or in conjunction with finite difference or other approximate methods can be useful in the study of plate elements in composite structures, moments and deflections in continuous plates, and in edge-supported plates, and behavior of viscoelastic plates.

S. K. Ghaswala, India

2767. Gallotly, G. D., Circular plates on a generalized elastic foundation, *ASME Trans.* **81**E (*J. Appl. Mech.*), 2, p. 297 (Brief Notes), June 1959.

2768. Traum, E., The design of folded plates, *Proc. Amer. Soc. Civ. Engrs.* **85,** ST 8 (*J. Struct. Div.*), 103–123, Oct. 1959.

Various design theories of folded plate structures are critically reviewed. The advantages and generality of the Method of Particular Loadings are stressed and an outline of its application is given. The method is illustrated by a numerical example.

From author's summary

2769. Hodge, P. G., Jr., Yield point load of an annular plate, *ASME Trans.* **81**E (*J. Appl. Mech.*), 3, 454–455 (Brief Notes), Sept. 1959.

The yield point load is computed for an annular plate, simply supported at its inner and outer edges and subjected to a uniform load. A previously published solution is shown to be incorrect.

From author's summary

2770. Leonards, G. A., and Harr, M. E., Analysis of concrete slabs on ground, *Proc. Amer. Soc. Civ. Engrs.* **85,** SM 3 (*J. Soil Mech. Foundations Div.*), 35–58, June 1959.

Slabs on the ground, because of deflections induced by temperature and moisture, can not have full contact with the soil. Author studies the case of a circular slab, partially supported, in which all the effects are symmetrical with respect to the center. The solution of the usual approximate equation $D\nabla_r^4 w = q - kw$ is represented in terms of Bessel functions (Schleicher); with reference to the case of soil reactions applied to all the slab, the distance of the point of zero deflection and four supplementary constants of integration have to be determined with the conditions along the parallel that divides the supported and unsupported zones.

Some diagrams, obtained with the aid of a digital computer, are given for concrete slabs. The calculated results are found to be in satisfactory agreement with experimental observations.

P. Pozzati, Italy

2771. Woodhead, R. W., An approximate partial differential equation for the bending of an unsymmetrical composite plate, *Austral. J. Appl. Sci.* **10,** 2, 123–137, June 1959.

An approximate partial differential equation is derived for the bending under lateral load of an unsymmetrical composite plate consisting of three separate plates, namely, the primary, secondary, and filler plates. The primary plate is treated as a plate with bending stiffness, the secondary plate is treated as a membrane without bending stiffness, and the filler plate is treated as offering resistance to transverse shears and the transverse normal force only. The equation is derived using variational calculus methods based on Castigliano's theorem of minimum potential and Reissner's theory for the bending of elastic plates. A stress distribution is assumed compatible with linear strain of the composite plate and with the equations of equilibrium in terms of stresses for any element. The basic equation of equilibrium for the plate is maintained by the use of a Lagrangian multiplier.

Depending upon various assumptions the composite plate yields an approximation to two-way singly-reinforced concrete slabs, and may be reduced to the case of a plate stiffened on one face by a membrane. Finally, the partial differential equation may be reduced to Reissner's equation and the classical equations for homogeneous plates.

From author's summary by G. Herrmann, USA

2772. Hicks, R., Asymmetrically plate-reinforced circular hole in a uniformly end-loaded flat plate, *Aero. Quart.* **10,** 2, 183–198, May 1959.

General expressions are obtained for the stress distribution in a flat plate end-loaded by equal principal stresses and containing a circular hole reinforced by an annular plate. The reinforcement is placed on one side of the plate only so that the other side remains flush. It is shown that the effect of an asymmetrically placed reinforcement is to induce, in the plate and reinforcement, bending stresses which are not negligible compared with externally applied direct stress. From particular examples it is found that reinforcement having practical dimensions can give rise to stress concentrations in the same order of magnitude as those in a similarly loaded plate containing an unreinforced hole. For practical purposes, data have been obtained which enable the designer to determine quickly the stress distributions associated with reinforcements and plates having a reasonably wide range of dimensions.

From author's summary by F. Correia de Araujo, Portugal

2773. Tamate, O., and Shioya, S., On the transverse flexure of an infinite strip with semicircular notches on both edges, *Bull. JSME* **2,** 6, 264–271, May 1959.

Title problem is solved on the basis of Poisson-Kirchhoff's theory. It is thus the counterpart of the plane-stress problem of the same notched strip solved by C. B. Ling ["Stresses in a notched strip under tension," *J. Appl. Mech.* **14,** pp. A275–A280, 1947]. The method of solution is also analogous to Ling's, with the exception that the unknown coefficients in the series solution are determined by a perturbation procedure. Interesting numerical results are presented for the distributions of bending moments, the stress-concentration factors, and the deflections of the strip.

Y.-Y. Yu, USA

2774. Silberstein, J. P. O., and Green, Beryl, Deformation of thick circular plates, Aero. Res. Lab. Melbourne, Austral., SM. 265, 23 pp., Apr. 1959.

Paper deals with problem of estimating distortion of glass reflector in 74-inch telescope at Mt. Stromlo. Actual reflector comprises circular dish with central hole, supported by nine spring-loaded pads. For their analysis, authors substitute circular plate of uniform thickness without central hole, and supported on rigid annulus of same surface area as spring-loaded pads. Actual solution is assumed to be a superposition of solutions of four problems, viz: (1) uniform heavy disk suspended from its upper surface without lateral constraint; (2) disk under uniform normal load on its upper surface supported on an annulus, the circumferential edge being subject to symmetric normal and shear loading; (3) disk under arbitrary linearly varying normal loading on circumferential edge; (4) disk subject to particular self-equilibrating shear and normal loading. No verification by actual measurement is given of calculated result.

Method of analysis follows Love's "Elasticity" [pp. 274–276], using a stress function for axisymmetrical plane stress distribution. Although this method can be applied to circular plates

[Timoshenko's "Elasticity," Chap. 13], it is not clear why authors chose it in preference to exact theory of thick plates [Love, pp. 465–487]. Moreover, the approximations made are needless. Rigorous solution by an energy method, without approximations, is less involved and more accurate (see Timoshenko's "Plates and shells," 2nd. edition, 1959, pages 293, 298, 305–307, 345, etc.).

F. A. Gerard, Canada

2775. Schneider, E., Load diffusion in isotropic quadrangles (in German), *Schiffstechnik* **6**, 31, 69–84, Apr. 1959.

In a plate of length l reinforced by longitudinal ribs spaced apart by $b < l/2$ and, on one side, extending beyond the edge of the plate, the ribs are subject to tensional forces of equal magnitude. On the opposite side, along the edge, the plate and the ribs transmit a uniformly distributed tensional load. The approximate solution suggested by H. Köller is verified by experiments and extended to cover the present case. Recommendations are included regarding the design of such load transmission zones.

G. Sonntag, Germany

2776. Volkersen, O., Clamped, edge-stiffened, thin rectangular plate under uniformly distributed load (in German), Dtsch. Versuchsanstalt Luftfahrt, Ber. 86, 63 pp., Mar. 1959.

After reviewing pertinent, rigorous large deflection theory and giving curves which permit almost direct calculation of stresses and deflection for case of infinitely long, clamped flat plate under uniform normal load, report presents approximate solutions to this problem based on methods of L. Foppl and W. Ritz. Report then presents a rigorous large deflection solution, and also an approximate solution based on Ritz method, for similar case in which edges of plate are stiffened flexurally by flanges of supporting members. Finally, an approximate large deflection solution, obtained by Ritz method, is presented for clamped, uniformly loaded, rectangular plate in which the four edges are stiffened by flanges of supporting members. Curves for stresses and deflections in these edge-stiffened plates are included and might be of considerable value to stress analysts working with aircraft and semimonocoque structures.

J. E. Goldberg, USA

2777. Burmistrov, E. F., Some problems of the theory of bending of isotropic plates with a cut-out of arbitrary shape (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 9, 143–147, Sept. 1958.

The solution of the first and second fundamental problem is given using the method of N. I. Muskhelishvili. Further, it is established that some results presented in the monograph by G. N. Savin ["Stress concentrations near openings," GITTL, 1951] are erroneous.

G. Herrmann, USA

2778. Koller, O., Influence fields for the main girder section loads of double beam plate girder systems (in German), *Bautechn. Arch.* no. 16, 30 pp., 1958.

Expressions are developed for influence fields of rectangular plates fixed to longitudinal edge members. Edge beams are simply supported at their ends but fixed against rotation about their longitudinal axis; they have torsional stiffness and bending stiffness in vertical direction, but not in horizontal direction. Influence fields are evaluated for moments and end loads under transverse load on edge member, using series expansions for vertical deflection and Airy's stress function. Example is applied to reinforced-concrete bridge structure and compared with other more elementary methods of analysis.

J. Van Winssen, Canada

Buckling

(See also Revs. 2689, 2707, 2758, 2779, 2847, 2854)

2779. Sherman, J., Laterally deflected columns, *Proc. Amer. Soc. Civ. Engrs.* **85,** ST 8 (*J. Struct. Div.*), 45–64, Oct. 1959.

Design formulas for the allowable stresses in laterally loaded and deflected columns of portal frames are developed from beam column theory. The combined action of the columns and the portal truss is considered in which it is assumed the truss has one or two panel lengths along the top of the column and the column base is fixed. The allowable stress formulas are presented in readily usable form. The more complex terms incorporating the geometry and the destabilizing effect of the column thrust are given in charts and tables, and also in approximate analytical form for practical ranges of construction. Comparisons are made with available specifications.

J. E. Duberg, USA

2780. Sandorff, P. E., Column end-fixity versus end-restraint, *J. Aero/Space Sci.* **26,** 11, 759–760 (Readers' Forum), Nov. 1959.

2781. Bleich, H. H., and Dillon, O. W., Jr., Nonlinear creep deformations of columns of rectangular cross section, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 517–525, Dec. 1959.

Creep deformations of columns of rectangular cross section are studied for the case of materials following the nonlinear law $\dot{\varepsilon} = (1/E)\sigma + \lambda\sigma^k$. The essential point of the paper is the following: The time rate of the curvature κ of an element of a bar loaded by a constant force P and an increasing bending moment $M(t)$ has bounds, which depend on P and on the instantaneous values of M and $\dot{M}$, but not on the history of M. In combination with the collocation method, this permits the formulation of ordinary differential equations for upper and lower bounds on the deformations. Closed solutions for the critical time are obtained for one bound, while the other requires numerical integration. The bounds which are a function of the initial eccentricity are reasonably close and are presented in tables and graphs. By qualitative reasoning it is further shown that the location of the actual critical time with respect to the two bounds is governed by the ratio of the column load P and the nominal Euler buckling load P_E of the column if it were elastic.

From authors' summary by J. Marin, USA

2782. Zuk, W., Beam column behavior of brittle members, *Mech. Engng.* **81,** 10, p. 45, Oct. 1959.

2783. Yamaki, N., Postbuckling behavior of rectangular plates with small initial curvature loaded in edge compression, *ASME Trans.* **81**E (*J. Appl. Mech.*), 3, 407–414, Sept. 1959.

Solutions are obtained by expansion of normal displacement in Fourier series, exact satisfaction of the compatibility equation for membrane stress and approximate satisfaction of the normal equilibrium equation by Galerkin's method. Boundary conditions in the plane include the cases where the unloaded edges are free, and held straight. The other edges have all combinations of simple support and clamping. Numerical results are given for square plates; tables and graphs are presented for maximum deflections, edge contraction and effective width for load carrying. Good agreement is found with results of Levy [NACA Rep. 737, 1942] and Coan [*J. Appl. Mech.* 1951]. Author is to be congratulated for his extensive coverage of a formidable nonlinear problem.

W. S. Hemp, England

2784. Nutt, J. G., The collapse of triangulated trusses by buckling within the plane of the truss, *Struct. Engr.* **37,** 5, 141–149, May 1959.

2785. Lepik, Yu. R., One possibility of solution of the stability problem of elasto-plastic plates in the precise formulation (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 8, 13–19, Aug. 1957.

Paper concerns the stability of plates of an elasto-plastic material whose mechanical properties in the plastic state are described by the flow-type stress-strain relation proposed by E. Reuss. The changes of internal forces caused by the deflections of plates are taken into account (this is why the words "precise formulation" are used in the title). The proposed solution of the problem is given by using a variational method. The example of buckling of circular plates is included. The comparison with the classical solution by A. A. Ilyushin ["Plastichnost" (Plasticity), OGIZ, 1948] does not reveal any considerable discrepancies.

M. P. Bieniek, USA

2786. van der Neut, A., Post buckling behavior of structures, AGARD Rep. 60, 33 pp., Aug. 1956.

The postbuckling behavior of plates and shells, investigated by means of large deflection analysis, is discussed. Reasons for interest in postbuckling behavior in aircraft design are reviewed and the three basic types of postbuckling behavior are described. The physical concepts are considered and the author concludes this discussion with nine fundamental facts about postbuckling behavior. The equations governing postbuckling behavior are then presented and the various methods of solution available are considered. A reader unfamiliar with this subject should be wary of the typographical errors that unfortunately appear in some of the equations. The final section of the paper summarizes available solutions for behavior after buckling. Flat plates and narrow cylindrical panels in longitudinal compression, flat plates under shear loads, and flat plates under thermal stresses are included.

The paper provides an excellent summary of postbuckling studies to the date of its preparation, August 1956. Some of the problems discussed have been the subject of more recent investigations; see for example: Alexeev, S. A., A postcritical study of flexible elastic plates, *Prikl. Mat. Mekh. USSR* **20**, 6, 673–679, Nov.-Dec. 1956; Masur, E. F., On the analysis of buckled plates, Univ. Mich., Engng. Res. Inst. Tech. Rep. no. 3, Sept. 1957; Stein, Manual, The phenomenon of change in buckle pattern in elastic structures, NASA TR R-39, 1959; Stein, Manual, Loads and deformations of buckled rectangular plates, NASA TR R-40, 1959.

R. R. Heldenfels, USA

Vibrations of Solids

(See also Revs. 2687, 2694, 2696, 2697, 2698, 2722, 2764, 2791, 2823, 2845)

Book—2787. Kupradse, W. D., Boundary problems of the theory of vibrations and integral equations [Randwertaufgaben der Schwingungstheorie und Integralgleichungen], Berlin, VEB Deutscher Verlag der Wissenschaften, 1956, viii + 239 pp. DM 27.60. (Paperbound)

A detailed account is given of work done by the author on boundary problems for the equation $\Delta^* u + k^2 u = 0$, $\Delta^* = \Delta + (\lambda + \mu \cdot \text{grad div}$, $k^2 = \sigma\omega^2/\mu$ where $u(u_1, u_2, u_3)$ is the displacement vector, λ and μ are elastic constants, σ is the density and ω the frequency of vibrations, with boundary conditions of the general form $\alpha u + \beta Tu = f$ on a closed surface S, sufficiently regular, where Tu denotes the stress vector corresponding to the unit normal to S. The book is a translation of the original (1950) Russian edition, but contains relevant changes and a new presentation of singular integral equations (Chapter V). The importance of the work lies in the fact that it covers a great number of particular cases (vibrating membranes, electromagnetic field, etc.) treated on a common, mathematically rigorous, ground.

R. Conti, Italy

2788. Maunder, L., On the work of a force crossing a beam, *Quart. Appl. Math.* **17**, 4, 437–439 (Notes), Jan. 1960.

Paper discusses the paradox originally mentioned by Timoshenko that a transverse force of constant magnitude "moving" across the length of an elastic beam, which is supported at its ends, "apparently" does no work and yet leaves the beam in vibration. Insofar as explaining this paradox is concerned, the whole matter can be simply disposed of by observing that a moving force is merely a convenient way of visualizing a certain time-dependent discontinuous force field. A force does not move in the sense that a material particle moves and the "motion" or the locus of the point of application of the force has nothing to do with the work done unless this motion happens to coincide with that of a real material particle. This paradox therefore, like all paradoxes, is caused by inconsistent interpretation of words and terms. Paper examines the situation where a constant force is applied through the intermediary of a hypothetical mass-less material particle, which may slide or roll on the beam, and arrives at the unsurprising conclusion that if friction force is the only tangential force at the contact, the particle cannot slide across the length of the beam and, if it is to roll across, an external torque is needed which furnishes the required work input for the beam to vibrate.

K. N. Tong, USA

2789. Yen, T. C., and Koo, S., Vibration of beam-mass systems with time-dependent boundary conditions, *ASME Trans.* **81**E (*J. Appl. Mech.*), 3, 353–356, Sept. 1959.

Using Laplace transforms the motion of a simply supported beam with one concentrated mass is found when the ends are uniformly accelerated. Closed-form frequency equations are given also for cantilever and fixed beams with a single mass and for simply supported and fixed beams with two equal symmetrically placed masses. Curves show the variation of the frequency parameter with ratio of concentrated mass to mass of beam for several modes and positions of the concentrated mass; for the beams with two concentrated masses only modes with antinodes at mid-span are considered.

G. B. Warburton, Scotland

2790. Baltrukonis, J. H., and Gottenberg, W. G., Thickness-shear vibrations of circular bars, *J. Acoust. Soc. Amer.* **31**, 6, 734–739, June 1959.

Author collected a number of known solutions of thickness-shear vibrations of circular bars. The theory is briefly outlined, followed by its application to both axisymmetrical and antisymmetrical modes. Cases considered in each mode are: (a) solid free bar, (b) solid bar clamped along its outer surface, (c) hollow bar with both surfaces free, (d) hollow bar clamped along its outer surface, and (e) hollow bar clamped along its inner surface. Frequency equations and certain ranges of natural frequencies for each case were given.

D. H. Cheng, USA

2791. Lebecque, R., The study of the flexural vibration of a bar cantilevered at one end and free at the other end (in French), *Rev. Univ. Mines* (9) **15**, 2, 58–79, Feb. 1959.

Using the dynamical deformation of a cantilevered beam the first part of the paper treats the theoretical problem of the flexural vibration of a beam with internal and external damping, expanding the definition of the force which produces the unit elastic deformation of a beam (for a cantilevered beam it is the load continuously distributed along the beam producing the unit displacement of the end of the beam). Natural vibrations with viscous damping and also forced vibrations with damping are treated, when the damping has the form $C\, y_t$ or $C\, (y_t)^r$, $r = 0; 1; 2; 3$. The damp-

ing due to the internal passive forces is discussed. The second part of the paper is devoted to the experimental investigations of the dynamical deformation of the cantilevered beam. Two methods are used: the direct method and the method of comparison. The damping is determined by a vibration and the analysis is verified. The explanation is followed by several very interesting figures with Lissajou's curves. D. Raskovic, Yugoslavia

2792. Baboev, N. N., On the influence of internal, inelastic resistance forces on forced transverse vibrations of beams (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 7, 125–129, July 1957.

A nonprismatic bar with free ends is considered. The damping force is assumed to be proportional to the velocity. Calculations are carried out with a view toward applications for ship hull vibrations. G. Herrmann, USA

2793. Newman, M. K., Viscous damping in flexural vibrations of bars, *ASME Trans.* **81**E (*J. Appl. Mech.*), 3, 367–376, Sept. 1959.

Energy dissipation in flexural vibrations is considered by introducing into the Timoshenko beam equation viscous damping terms proportional to the time rate of extensional strain. Two modes of wave transmission arise from the roots of a quartic equation. On the lower mode, a solution is indicated in terms of characteristic functions which represent the damped natural vibrations. For a specified range of values of damping, the amplitudes of natural vibrations are governed by characteristic damping factors which exhibit a maximum in the region of frequencies where wave velocities are dispersed. There can be no frequency cut-offs. In the higher mode of wave motion, the characteristic damping factors exhibit a monotone increase toward short wavelength limits analogous to those obtained in the Bernouilli-Puler-Sezawa equation.

From author's summary by H. C. Reggini, Argentina

2794. Tu, Y.-O., and Handelman, G., Problems in the dynamics of elastic systems under initial stress, AFOSR TN 59-406 (Rensselaer Polytech. Inst., Dept. Math. Rep. 25; ASTIA AD 214 503), 74 pp., May 1959.

The eigenvalue problems associated with vibration and stability of beams under initial axial stress and flat plates under initial plane stress are formulated from variational principles for general structural members. These eigenvalue problems can be studied by means of variational principles or through the solution of appropriate differential equations with corresponding boundary conditions.

The ordinary differential equation for the vibration of beam is of the form $u^{iv} + \gamma^2[\Psi(x)u']' = \beta^4 u$, where the initial stress $\Psi(x)$ is compressive for $\Psi(x) > 0$. Upper bounds for β^4 may be obtained from minimum principles, in particular Rayleigh quotients. Comparison theorems which provide lower bounds are established for this particular type of eigenvalue problems. The ordinary Southwell method for lower bounds of the first eigenvalue can be applied directly for the case $\Psi(x) \leqslant 0$ for all x throughout the entire length of the beam; however, for other cases, similar methods are formulated and proved accordingly. In addition, the Schwarz iteration method can be used to find both upper and lower bounds for the first eigenvalue.

Approximate solutions for small γ^2 can be obtained by the perturbation theory of Rellich for which the perturbed differential operator is of lower order than the unperturbed problem. If, however, the beam is everywhere under tension, no critical load exists. Consequently, γ^2 could be very large, and β^4 increases monotonically with respect to γ^2. By writing the differential equation in the form $[\Psi(x)u']' + (1/\gamma^2)u^{iv} = (\beta^4/\gamma^2)u$, an approximate solution can be found for large γ by the method of singular perturbation for which the perturbed differential operator is of higher order than the unperturbed one.

Perturbation solutions have been carried out for another example of a thin, but long, flat plate simply supported on all edges and subjected to parabolic temperature distribution along its width. Numerical results do indicate the existence of critical loads. From authors' summary by T. H. H. Pian, USA

2795. Cox, H. L., and Benfield, W. A., Vibration of uniform square plates bounded by flexible beams, *J. Acoust. Soc. Amer.* **31**, 7, 963–966, July 1959.

Author uses finite difference methods to estimate the fundamental frequency of flexural vibration of an isotropic elastic square plate pinned along its edges to torsionless flexible beams, which are in turn supported at the four corners of the plate. For vanishing Poisson ratio the results obtained by this method are compared with those computed by Rayleigh's method and the method of collocation. L. E. Payne, USA

2796. Schuster, K., and Vosahlo, H., The calculation of bending vibrations in quadratic crystal plates (in German), *Acustica* **9**, 1, 265–269, 1959.

The frequency of the natural vibration, fundamental and first overtone, of square crystal plates as used in special crystal systems and wedge sections is calculated using the method of Ritz under the assumption that the two diameters parallel to the edges are nodal lines. The calculation is confirmed by experimental measurements. From authors' summary

2797. Hearmon, R. F. S., The frequency of flexural vibration of rectangular orthotropic plates with clamped or supported edges, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 537–540, Dec. 1959.

Rayleigh's method, together with use of characteristic functions of the classical beam, is applied to the frequency study indicated by the title. In similar study of isotropic rectangular plates, Rayleigh's method was used by Warburton [*Proc. Instn. Mech. Engrs.* **168**, p. 371, 1954], and Ritz's method by Young [*J. Appl. Mech.* **17**, p. 448, 1950]. While Ritz's method involves considerable amount of computation work, Rayleigh's method may not be accurate and inclusive enough for cases which easily develop modes with nodal lines not approximately parallel to the sides of the plate; for instance, author's case 4 in Table 1 in which the plate has two adjacent edges clamped and the other two supported. Reviewer feels that a two-term approximation in the Ritz method will greatly increase the accuracy for many modes but will only increase computation work by a reasonable amount. This is apparently so as may be seen from Young's results, although he used a nine-term approximation in most of his cases.

Y.-Y. Yu, USA

2798. Mindlin, R. D., and Medick, M. A., Extensional vibrations of elastic plates, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 561–569, Dec. 1959.

A finite system of approximate, two-dimensional equations of extensional motion of isotropic, elastic plates is derived as follows. The components of displacements are expanded into series of Legendre polynomials of the thickness coordinate with coefficients depending on the two coordinates in the plane of the plate. The three-dimensional equations of motion are then integrated across the thickness and the resulting infinite system of two-dimensional equations is truncated to produce a system of five equations. These equations separate into a group of three coupled equations describing the extensional, the lowest thickness-stretch and the lowest thickness-shear mode, and two independent equations describing each a face-shear mode. In order to correct for the effect that the frequencies of these modes—with

the exception of the extensional and the lowest face-shear mode—are influenced by higher modes, certain coefficients are added in the equations and determined in such a way that agreement is obtained for long wavelengths. The spectrum of frequencies for real, imaginary and complex wave numbers in an infinite plate is explored in detail for various values of Poisson's ratio and compared with the corresponding exact solution of the three-dimensional equations. A. I. van de Vooren, Holland

2799. Yu, Y.-Y., Flexural vibrations of elastic sandwich plates, AFOSR TN 59-188 (Polyt. Inst. Brooklyn, Dept. Mech. Engng.; ASTIA AD 211 219), 29 pp., Mar. 1959.

Paper presents flexure vibration studies of sandwich plates, in which the effect of transverse shear and that of the rotatory inertia is included. A frequency equation is given for the infinite sandwich plate in plane strain, without imposing limitations upon the magnitudes of the ratios between the thicknesses, material densities, an elastic constant of the core, and faces of the sandwich. For ordinary sandwich plates, the results are simplified and discussed in detail. It is also indicated how the results for infinite plates may be used for simply supported plates that have finite lengths in one direction.

A numerical example is given for a typical sandwich plate. The importance of including the shear and rotation effects in the sandwich-plate theory is also indicated.

A. L. Petre, Roumania

2800. Simon, G., Determination of characteristic frequencies of rectangular plates with stiffeners parallel to the edges and Navier-type boundary conditions (in German), *Stahlbau* **27**, 12, 309-314, Dec. 1958.

Paper makes it possible to determine characteristic frequencies for most of the different forms of stiffening without a great knowledge of Raleigh-Ritz energy method. It is closely related to research in the field of elastic stability of stiffened plates, and DIN 4114 standards are widely used. Fundamental frequencies are computed for a few forms of stiffening, and some types of lowest rigidities are plotted graphically, by means of which frequencies of other forms of stiffening can be approximately computed. The lowest rigidity the stiffeners must have in order to keep fundamental frequency of stiffened plate larger than the frequency of nonstiffened plate has no parallel in the stability theory. H. Fernandez Long, Argentina

2801. Gustafsson, O. G., and Kane, T. R., Axially symmetric extensional vibrations of a circular disk with a concentric hole, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 541-545, Dec. 1959.

On the basis of the Kane-Mindlin theory of high-frequency extensional vibrations of plates [*J. Appl. Mech.* **23**, p. 277, 1953], frequency equation is derived for the title problem. Limiting cases include symmetric extensional vibration of the solid circular disk, that of the thin cylindrical shell, low-frequency vibration of thin plate in generalized plane stress, and the lowest radial mode of a thin ring. Y.-Y. Yu, USA

2802. Ellington, J. P., and McCallion, H., The free vibrations of grillages, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 603-607, Dec. 1959.

Frequency equations and modal shapes are derived for the transverse vibrations of beam grillages consisting of two sets of equally spaced uniform beams, the mass of the beams and associated plating being taken as lumped at the nodes. Solutions are found through the application of finite difference calculus for the following boundary conditions: (1) all edges simply supported; (2) two opposite edges simply supported with remaining edges free; (3) two opposite edges simply supported with remaining edges damped. The solution for the case of a grillage with any arrangement of simple, free, or fixed boundary conditions is readily found from these results. A. W. Coutris, USA

2803. Wroe, D., and Nissan, A. H., Some observations on the vibration and whirling of continuously loaded spindles, *Text. Res. J.* **29**, 4, 331-348, Apr. 1959.

Natural frequencies in flexure of uniform and uniformly-tapered cantilevers are derived using Rayleigh and Dunkerley methods. Results are compared with natural frequencies and critical speeds obtained by experiment. Theoretical expression is derived giving critical speed of spindle carrying distributed package.

J. D. Robson, Scotland

2804. Coleman, R. P., and Feingold, A. M., Theory of self-excited mechanical oscillations of helicopter rotors with hinged blades, NACA Rep. 1351, 39 pp., 1958.

See AMR **11** (1958), Rev. 69.

2805. Srinivasan, P., Internal damping of thermal origin in thin wires, *ASME Trans.* **81**E (*J. Appl. Mech.*), 3, 456-457 (Brief Notes), Sept. 1959.

The object of this note is to study the effects of wire diameter, length, and material of the wire on its damping ability. This knowledge is essential in order to understand the performance of wire damping devices for alleviating high vibratory stresses set up in turbine blades by such effects as resonance, rotating stall, and stall flutter. Di Taranto has recently presented a report on such a device and indicated the need for a study such as undertaken in this note. From author's summary

2806. Gurtin, M. E., Steady-state response of linear vibration systems with viscous damping, *ASME Trans.* **81**E (*J. Appl. Mech.*), 3, 461-462 (Brief Notes), Sept. 1959.

Author transforms basic matrix equation for forced vibration into first-order equation using form suggested by Foss. For systems with N degrees of freedom, $2N$ eigenvectors and eigenvalues occurring as conjugate pairs are obtained from homogeneous equation for transformed first-order equation. Author shows that due to orthogonality each mode may be normalized to obtain diagonal matrix. Author then shows that solution can be written immediately from the known eigenvectors and eigenvalues.

A. Pauw, USA

2807. Kerwin, E. M., Jr., Damping of flexural waves by a constrained viscoelastic layer, *J. Acoust. Soc. Amer.* **31**, 7, 952-962, July 1959.

Author reports theoretical and experimental study of damping of plate flexural vibration by viscoelastic (VE) layer constrained by stiff material that is thinner than plate. Shear viscosity in VE layer is taken as damping mechanism. Fair agreement between calculated and measured damping is observed for small damping; calculated value is larger. Maximum ratio of composite structure damping to damping of VE material is about 1/2 when plate and constraining layer have same stretching stiffness.

V. Salmon, USA

2808. Rozhanskii, V. N., and Dekartova, N. V., The relationships in the damping of torsional oscillations of metal wires, *Soviet Phys.—Doklady* **3**, 4, 838-841, Apr. 1959. (Translation of *Doklady Akad. Nauk SSSR (N. S.)* **121**, 2, 274-276, July/Aug. 1958 by Amer. Inst. Phys., Inc., New York, N. Y.)

Paper attempts to account for time-dependence of logarithmic decrement and period for finite amplitude torsional oscillations. Experimental data for monocrystalline and polycrystalline zinc and for polycrystalline copper wires are given. Authors conclude that variation of logarithmic decrement and period may be ex-

plained by dependence of shear modulus and internal friction on amplitude and time. J. C. Truman, USA

2809. Tobias, S. A., Design of small isolator units for the suppression of low-frequency vibration, *J. Mech. Engng. Sci.* **1**, 3, 280–292, Dec. 1959.

The customary linear vibration isolators are unsuitable for the suppression of low-frequency vibration in applications where, in addition to steady-state vibration, the danger of shock excitation exists. Linear suspensions which ensure a low natural frequency are necessarily very soft and, as a result, excessive large deflections will arise during steady accelerations or shock excitation. These undesirable features are not encountered with symmetrical nonlinear suspensions, which under steady-state vibration excitation behave like linear springs, but when suffering large deflections from their "working point" become progressively stiffer. One of the spring elements which has the required spring characteristic is the "sine spring." The properties of this spring element are summarized and the various ways of coupling sine springs and ordinary springs are discussed. Several designs of isolator units, incorporating sine springs for the vertical degree of freedom and leaf springs for the horizontal degree of freedom, are described.

The Appendices contain a short discussion of various "constant-force" springs suitable for low-frequency suspensions, a description of the experimental equipment used, and some experimental results regarding the behavior of sine spring suspensions.

From author's summary

2810. Edelman, S., Brooks, R., Saito, S., Jones, E., and Smith, E. R., A stroboscopic vibration analyzer, *J. Res. Nat. Bur. Stands.* **63C** (*Engineering and Instrumentation*), 2, 97–103, Oct./Dec. 1959.

An instrument for studying the amplitude and phase relations which exist in complex periodic processes is described. The process treated here is vibration of complicated bodies. The motion at each point of interest is detected by a vibration pickup. The signal from each pickup is heterodyned with a common signal that differs from the vibration frequency by a small amount to produce a set of signals at the difference frequency. The desired relations are exhibited at the difference frequency which is low enough to give a slow motion effect. The output circuitry allows scope for ingenuity to choose a presentation suited to a particular problem. From authors' summary

2811. Klyukin, I. I., The effect of a vibrometer on the motion of a vibrating surface, *Soviet Phys.—Acoustics* **5**, 1, 36–42, Aug. 1959. (Translation of *Akust. Zh. SSSR* **5**, 1, 38–45, Jan./Mar. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Paper treats the problem of the reaction of a vibrometer on rods and plates in which flexural waves are propagating. The problem is idealized to the case of plane steady waves in an infinite rod (plate problems are closely related), having in frictionless contact with it (along its entire width) an obstacle (the finite-mass vibrometer). It is assumed that contact length (along rod axis) is small compared to the wavelengths of interest. Damping is taken into account.

Author gives formulas for the attenuation of the transverse vibrations in infinite rods and plates by the vibrometer. It is shown from these expressions that, at the moderately high and very high frequencies, the wave attenuation in thin plates and rods can become larger. J. Miklowitz, USA

2812. Bordoni, P. G., and Nuovo, M., A tuned capacitive detector for high frequency vibrations (in English), *Acustica* **8**, 6, 351–362, 1958.

A new apparatus for studying the longitudinal vibrations of plates in the megacycle range has been developed using an electrostatic drive and detector. The mechanical vibrations are converted to an a-c signal by means of a d-c polarizing voltage applied to the probe as is normally done for electrostatic microphones.

The detection circuit is tuned on the vibration frequency; in this way a high sensitivity has been obtained. Detailed information is given on the circuitry and on upper frequency limits for the application of the apparatus in the measurement of the mechanical properties of plates.

Experimental data are given on the longitudinal sound velocity spectra, on the damping of various plates and on their dependence on temperature. From authors' summary

2813. Bordone-Sacerdote, C., Measurements on damping materials sprayed on steel tubes (in English), *Acustica* **9**, 2, 75–78, 1959.

Some experiments are described concerning tubes vibrating longitudinally and sprayed with damping materials. The results fit a simple theory, allowing the elastic parameters of the damping material, and its efficacy when the metallic support is not completely sprayed, to be calculated.

From author's summary

2814. Bohn, L., and Oberst, H., Information about the mechanical behaviour of polymers under impact loads from vibration experiments (in German), *Acustica* **9**, 1, 191–199, 1959.

Vibration measurements have become increasingly important in the development and testing of plastics, especially since they yield information about molecular relaxation processes in high polymers which largely determine the behavior of the plastics under short-time loading.

It is shown in which way the measured curves of Young's modulus and its loss factor versus temperature for a series of frequencies allow conclusions to the behavior of the substances under shock load (shock bending). Experimental results obtained with polypropylene and polytrifluorchlorethylene agree with and illustrate the theoretical considerations.

From authors' summary

Wave Motion and Impact in Solids

(See also Revs. 2715, 2721, 2764, 2793, 2811, 3182)

2815. Caughey, T. K., Response of a nonlinear string to random loading, *ASME Trans.* **81E** (*J. Appl. Mech.*), 3, 341–344, Sept. 1959.

In this excellent paper, a study of a nonlinear string subjected to a random excitation has been made. The method of equivalent linearization applied to nonlinear differential equations with harmonic excitation has been slightly modified and applied to this problem.

Author shows that in the case of deterministic loading, the additional stress induced by the stretching of the string reduces the mean squared deflection at every point compared with that for the equivalent linear string. M. M. Stanisic, USA

Book—2816. Proceedings of the conference on the properties of materials at high rates of strain, April 30–May 2, 1957, London; Institution of Mechanical Engineers, viii + 268 pp.

Beginning with an excellent review by Cottrell of the general principles of elastic waves, plastic waves, cracks, slip in crystals, dislocations and their propagation, yield, and fracture, these papers cover the principal areas of experimental techniques, metal working, impulse loading and stress waves, nonmetallic materials, and basic properties.

Both theory and practice are considered. Methods of making measurements, equipment for load application, results, and interpretation in the light of theory are included.

The symposium papers provide a broad coverage and present a good picture of the current situation.

A. G. H. Dietz, USA

2817. Buchwald, V. T., Transverse elastic waves in an internal stratum, *Quart. J. Mech. Appl. Math.* **12**, 1, 43–51, Feb. 1959.

This paper treats the propagation of transverse waves in an elastic stratum bounded by two elastic media of infinite extent. The author shows that there are always an infinite number of discrete modes of vibration and that the vibrations in each mode are either symmetric or antisymmetric about the center plane if, and only if, the two infinite media are identical.

D. R. Bland, England

2818. Gorshkov, N. F., The influence of absorption on the propagation of elastic impulses (in Russian), Avtoref. Diss. Kand. Fiz.-Matem. Nauk, MGU, Moscow, 1957; *Ref. Zh. Mekh.* no. 7, 1958, Rev. 7941.

2819. Giangreco, E., Elastic instability by association of pulsating loads (in English), 9th Congrès Intern. Appl. Mécan., Univ. Bruxelles, 1957; **7**, 89–97.

2820. Eringen, A. C., and Samuels, J. C., Impact and moving loads on a slightly curved elastic half space, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 491–498, Dec. 1959.

Two-dimensional Fourier transforms are employed to treat the two-dimensional dynamic problem of elastic half space having a slightly wavy boundary. The various boundary curves considered include square and triangular bumps and holes, and sinusoidal and periodic boundaries. The number of different types of surface loadings considered are: (a) Normal tractions and zero shear, (b) impulsive normal tractions and zero shear, (c) suddenly applied normal tractions and zero shear, (d) concentrated normal load and zero shear, (e) concentrated impulsive load and zero shear, (f) pulsating normal load and zero shear, (g) moving loads, (h) pulsating moving loads, (i) vertical and horizontal loads, (j) moving vertical loads. Stress and displacement components for special cases of the loads described in (a, c, f and g) acting on a sinusoidal boundary lead to a solution which requires evaluation of a single indefinite integral. Closed-form results are given for a uniform pulsating pressure load.

From authors' summary by D. Williams, England

2821. Davids, N., Transient analysis of stress-wave penetration in plates, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 651–660, Dec. 1959.

Paper investigates the propagation of a transient stress pulse concentrated at the point $r = 0$, $z = 0$ of the thick plate $0 \leqslant z \leqslant d$, the length d being of the order of a wavelength. In the first case considered it is assumed that on $z = 0$, $\sigma_z = (2\pi r)^{-1}\delta(r)e^{pt}$, $\tau_{rz} =$ and that on $z = d$, $\sigma_z = \tau_{rz} = 0$. The basic equations are solved by the use of what is essentially a Hankel transform, and the stress σ_z along the axis $r = 0$ is calculated in the form of an infinite integral. This integral is reduced by an expansion method (introduced by Cagniard for the solution of geophysical problems) which has an immediate physical interpretation. From the special solution considered the solution corresponding to a concentrated stress pulse of general time variation $P(t)$ is obtained by using the theory of the Laplace transform.

The use of the general formulas is illustrated by considering the time variation of the normal stress σ_z along the axis of an aluminum plate of 1-in. thickness when a 5-microsec exponentially decaying pressure pulse is applied to the surface. The physical implications of the solution are discussed and certain limiting cases examined critically.

I. N. Sneddon, Scotland

2822. Kurtze, G., Bending wave propagation in multilayer plates, *J. Acoust. Soc. Amer.* **31**, 9, 1183–1201, Sept. 1959.

Approximate, equivalent circuits for flexural wave propagation are investigated both by circuit analysis and analog computation in order to determine the damping effect of (a) viscous liquid between two plates and (b) an air-filled porous material placed between a plate and an array of masses. These theoretical results are confirmed by direct measurements, and it is found that both (a) and (b) are capable of providing high damping in certain frequency ranges. The damping properties of (a) and (b) are compared with those of (c) a single layer of damping material applied to one surface of a plate and (d) a typical sandwich-type damping layer.

J. W. Miles, USA

2823. Gazis, D. C., Three-dimensional investigation of the propagation of waves in hollow circular cylinders, Part I, Analytical foundation; Part II, Numerical results, *J. Acoust. Soc. Amer.* **31**, 5, 568–578, May 1959.

In part I author investigates the propagation of free harmonic waves along a hollow circular elastic cylinder. Using Helmholtz potentials the author obtains the characteristic equation appropriate to the hollow cylinder. Axially symmetric waves, the limiting modes of infinite wavelength, and a special family of Lamé equivoluminal modes are derived and discussed as degenerate cases of the general theory.

In part II author uses a high-speed digital computer to evaluate the frequency spectrum for a number of thickness ratios in the case of one and two circumferential waves.

This paper parallels the work of Greenspon, [J. E. Greenspon: (1) Doctoral dissertation, The John Hopkins University June 1956; (2) Proc. Third U.S. Nat. Congr. Appl. Mech. (1958), pp. 163–173; AMR **12**(1959), Rev. 5997]; however, author presents data for a number of the higher modes not treated by Greenspon. Therefore as far as results are concerned, the two pieces of work complement each other.

T. K. Caughey, USA

2824. Newmark, N. M., A method of computation for structural dynamics, *Proc. Amer. Soc. Civ. Engrs.* **85**, EM 3 (*J. Engng. Mech. Div.*), 67–94, July 1959.

A general numerical integration for structural dynamics problems is given in which damping, nonlinearity, and plastic response can be included. Integration formulas have two adjustable parameters. In order to avoid spurious damping in the solution, it is shown that the adjustable parameter in the integration formula for velocity must be based on a linear variation of acceleration over the integration interval. Tables are given for (1) convergence and stability limits with different values of the integration parameter for displacement and (2) the effect of the length of integration interval on the error of the vibration period, maximum response to initial velocity, and rate of convergence. Problems of various types of structures are discussed in some detail. A method is given for arched or curved structures in which members are not allowed to change in length. This is done by specifying constraints which reduce the number of degrees of freedom. Numerical examples of applications are not given. Paper is a fruitful source of ideas for many problems.

R. B. McCalley, Jr., USA

2825. Stuart, D. A., and Ruoff, A. L., Impact loading of structures using double acting bombs, *Proc. Soc. Exp. Stress Anal.* **16**, 2, 17–26, 1959.

The experimental investigation of the behavior of structures to impulsive loading has suffered from the lack of a device which could rapidly develop a reproducible and controllable force-versu-

time loading history. For this reason the double acting "bomb" discussed herein was developed. Specifically, authors have attempted to develop a device which would give a nearly rectangular force-versus-time history, although the device can be used to develop many different wave forms. The bomb is a piston with an explosive charge on each side of the piston. If the piston is not attached to the structure the first charge applies the load and firing the second charge removes the load from the structure.

From authors' summary

2826. Knopoff, L., and Gilbert, F., First motion methods in theoretical seismology, *J. Acoust. Soc. Amer.* **31**, 9, 1161–1168, Sept. 1959.

This is the first paper in a series from the Institute of Geophysics of the University of California at Los Angeles, in which a variety of approximate solutions for the oscillatory displacement field due to a point-source of disturbance in an elastic medium is given. The general approximation method, of which the paper under review contains the basic exposition, is concerned with the *first motion* caused at a distant point by the onset of the disturbance. This is done by establishing an asymptotic series in powers of $t - t_0$, where t is the time and t_0 the arrival time of the disturbance, and retaining only the first terms therein. Two examples are given which illustrate the method.

A. E. Scheidegger, Canada

2827. Shaw, W. A., and Allgood, J. R., Blast resistance of reinforced concrete beams influenced by grade of steel, *J. Amer. Concr. Inst.* **30**, 9, 935–945, Mar. 1959.

Method for determining the influence of grade of reinforcing steel on blast resistance of beams is based on preselected criteria of failure. The peak dynamic load capacity is calculated for beams of a given configuration but having different percentages and grades of reinforcing steel. These calculations are made for blast-type loads of different duration. Plots of the results indicate that suitability of various steel grades will depend primarily on maximum permissible deflection, characteristics of the loading, and amount of tension steel used.

From authors' summary

2828. Clausing, D. P., Impact of cylinders of different areas, Proc. Fourth Midwest. Conf. Solid Mech., Austin, Texas, Sept. 1959; Austin, Tex., Univ. Press, 1959, 349–357.

2829. Krafft, J. M., and Sullivan, A. M., Effect of grain size and carbon content on the yield delay-time of mild steel, *Trans. Amer. Soc. Metals* **51**, 643–659, 1959.

Authors use their modified Hopkinson bar technique to subject mild-steel cylinders ½ in. in diameter and ½ in. long to nearly rectangular pulses of stress rising to their maximum in about 5 microseconds and holding that maximum for about 600 microseconds. Strain rate is determined from decrease in stress indicated on loading bar and delay time from time at which this decrease occurs. Tests were made at 5 temperatures between −60 and +125 C on specimens from three groups of steels to study effect of changes in microstructure and changes in carbon content. On the basis of a careful analysis of the data the authors show convincingly that the initiation of yield, which is associated with the upper yield point, is related to microstructure in a different manner than the post yield plastic flow, which is associated with the lower yield point. The supported stress for the first was found to depend on the size of the pearlite patches more strongly than upon the ferrite grain size for either normalized or annealed steels. The flow stress at a given high strain rate for the second was dependent upon the distance between pearlite patches and also upon the grain size more strongly than upon the pearlite patch size. Increase in carbon content increased the stress supported for a given delay time in a continuous manner provided that the manganese content and de-oxidizing practice were similar and provided that a correction was made for variation in pearlite patch size.

W. Ramberg, Italy

Soil Mechanics: Fundamental

(See also Rev. 2820)

Book—2830. Todd, D. K., Ground water hydrology, New York, John Wiley & Sons, Inc., 1959, xii + 336 pp. $10.75.

The first textbook in this field which should be called geohydrology rather than hydrogeology. It has been almost tradition that authors of hydrology textbooks obtain the assistance of a geologist in preparation of a chapter on ground water. This book covers occurrence of ground water, its movement, ground water and well hydraulics, water wells, water-level fluctuations, quality of water, surface and subsurface investigations, artificial recharge, sea water intrusion, legal aspects, model studies. Thus we have not only hydrology, but also ground-water engineering and legal interpretation.

The book is designed not only for students but for men working in various fields close to ground water. Therefore theoretical part is very concise; good sketches and illustrations facilitate reading. Terminology, although carefully selected, is not yet definitely established: reviewer cannot agree with the word coefficient for dimensional factors, e.g., coefficient of permeability, p. 50. Several names are regretably mispelled: Edmé Mariotté instead of Edme Mariotte, p. 3, Bakhameteff instead of Bakhmeteff, pp. 54 and 73. The title page is unusually "cubistic" and suggests the divining rod or twig which the author definitely condemns on p. 231.

S. Kolupaila, USA

2831. Trollope, D. H., and Morgan, J. R., Stress systems within simple slopes of granular materials, *Instn. Engrs., Australia, Civ. Engng. Trans.* CE **1**, 1, 18–26, Mar. 1959.

Paper presents the "Systematic arching theory" developed previously by one of the authors, in which a mass of soil is represented by an aggregate of systematically packed uniformly sized smooth and rigid spheres. The packing of spheres is assumed to be nearly rhombohedral and the outside slope to be stable only when it describes an angle of 30° with the horizontal. Principal normal and shear stresses are calculated both for the "rigid base" and the "full arching" conditions. Experiments in which only the base pressure distribution (σ_y) was measured offer a reasonable confirmation of theoretical predictions. The solution is then extended to a determination of the stability of slopes.

Solution suffers from ignoring the densest possible (tetrahedral) packing, as well as the omission of friction and cohesive effects between particles. The assumption of uniform spheres may be applicable to special granular aggregates (smooth sand, catalyst, glass beads), but its uncritical extension to general predictions of permissible slopes is not warranted. A considerable extension of theoretical work and further experiments appear to be desirable before the "systematic arching theory" can be accepted as a tool of engineering design considerations.

N. A. Weil, USA

2832. Uchida, I., Matsumoto, R., and Arima, T., Effects of remold on the consolidation of soil (in Japanese), *Trans. Japan Soc. Civ. Engng.* **55**, 10–14, May 1958.

When natural soil is remolded, the properties of this soil in consolidation change. As is well known, the $\log_{10} p - e$ curve becomes a straight line when the load is small, and the total compression is larger. Compression index, coefficient of consolidation and permeability become smaller, and primary compression

ratio becomes larger when the soil is remolded. The effect of the difference of load-increment seems not to be large.

From authors' summary

Courtesy of the Editorial Committee of the Japan Society of Civil Engineering

2833. Thornburn, T. H., and Larsen, W. R., A statistical study of soil sampling, *Proc. Amer. Soc. Civ. Engrs.* **85,** SM5 (*J. Soil Mech. Div.*), 1–13, Oct. 1959.

This is a study undertaken to determine the number of samples needed to obtain reasonable correlations between pedologic soil types and their engineering properties. Data from four DeWitt County soils give a quantitative indication of the value of pedologic information in planning, designing and constructing highways and airports in Illinois. From authors' summary

2834. Haythornthwaite, R. M., The mechanics of the triaxial test for soils, Brown Univ., Div. Engng. TR 1 (Contract DA-19-020-ORD-4566), 33 pp., Apr. 1959.

When interpreting the results of triaxial tests the assumption is usually made that the stress is uniform throughout the sample. The author shows that nonuniform stress distributions can also satisfy the yield and boundary conditions and that under these conditions the ratio of the axial to the radial pressure depends upon the intermediate principal stress. In the case of axial compression the normal formula assuming a homogeneous stress distribution gives the maximum value of this ratio and thus, according to limiting equilibrium theory, the loading path must cross a zone where failure is possible with a nonuniform stress distribution. The experimental data at present available are inadequate to enable definite conclusions to be drawn but they do indicate that the solution of the problem is not unique.

A. Marsland, England

2835. Hansbo, S., A new approach to the determination of the shear strength of clay by the fall-cone test, Royal Swedish Geotechnical Institute, Proceedings, no. 14, 48 pp., 1957.

This paper presents a new approach to the interpretation of the fall-cone test.

The region of failure created around the cone when dropped into the clay is studied both theoretically and experimentally. A theoretical and experimental investigation of the cone motion has also been carried out.

A relation is established between the depth of cone penetration b and the undrained shear strength τ_f of the clay. Approximately, $\tau_f = KQ/b^2$, where Q is the weight of the cone and K is a constant whose magnitude depends upon the cone angle β. For "undisturbed" clay, K depends also upon the type of sampler used.

The values of τ_f obtained from this formula are compared with the undrained shear strength values obtained from other laboratory tests and from the field vane test. Tables are included giving the corresponding values of τ_f and b for undisturbed clay taken with the ordinary piston sampler and for remolded clay.

From author's summary

2836. Kallstenius, T., and Bergau, W., Investigations of soil pressure measuring by means of cells, Royal Swedish Geotechnical Institute, Proceedings, no. 12, 50 pp., 1956.

Tests were made on a cell flush with a boundary aiming at an accuracy of 5% over 10 years. A flexible membrane with a travel of 0.0001 of the diameter of the cell was selected to reduce scatter. This membrane must be hard and smooth. Pressure was measured by a Bourdon gage through a capillary tube filled with silicone oil, prestressed to reduce the effect of gas. Electric contacts limited maximum membrane travel. A diameter of 10 inches was used to be at least 50 soil grain diameters and to reduce variations from nonhomogeneous soil. Variation of soil modulus of elasticity with pressure, effect of repeated tests and vibrations, and test tank boundary conditions were considered and their importance stressed. E. S. Barber, USA

Soil Mechanics: Applied

(See Rev. 2831)

Processing of Metals and Other Materials

(See Revs. 3142, 3209)

Fracture (Including Fatigue)

(See also Revs. 2723, 2724, 2782, 2816, 3161)

2837. Tolkachnik, S. V., On impact fatigue under conditions of stress concentration (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 5, 106–110, May 1958.

The fatigue properties of two Russian materials, St. 45, a medium carbon steel (yield and tensile strength 48 and 77 kg/mm^2) and St. 40 X, an oil-tempered low-alloy steel (yield and tensile strength 172 and 200 kg/mm^2) are compared under conditions of repeated tensile sinusoidal and impact loading. The specimens were circular bars, diameter 5 mm for impact loading and 7.5 mm for sinusoidal loading. In comparison with smooth bars the influence of a hyperbolical circumferential groove (Neuber groove) was investigated with a ratio $\alpha/\rho = 14.3$ between the radius α of the minimum section of the bar and the radius of curvature ρ at the bottom of the groove, giving rise to a theoretical stress concentration factor $K_t = 3.98$. A shallow and a deep groove were investigated, the ratio between the depth t and ρ being about 1 and 10, respectively. The total impact time (measured by means of wire resistance strain gages) was 1.5×10^{-3} sec, the frequency ten impacts per second. The sinusoidal loading had a frequency of 750 cycles per minute. Plastic flow was studied by sectioning the test specimens and applying Fry's etching method.

If: K_1 = ratio between the fatigue strengths of the smooth and the notched bar under sinusoidal loading; K_2 the same for impact loading; α = ratio between the fatigue strengths under impact and sinusoidal loading of similar test specimens; and $\beta = (K_2 - K_1)/K1$, the results can be listed as follows:

	α	β	K_1	K_2	
St. 45	1.0	—	—	—	smooth bar
	0.86	0.17	1.37	1.60	shallow groove
	0.83	0.21	1.64	1.98	deep groove
St. 40 X	1.24	—	—	—	smooth bar
	0.97	0.27	1.36	1.73	shallow groove
	0.83	0.50	2.18	3.26	deep groove

The stress-concentration factor on impact loading is higher, especially with the alloy steel. On the other hand for this steel the fatigue strength of smooth specimens under impact loading is about 25% higher. All values are well below the theoretical stress-concentration factor; perhaps this is due to the relatively small dimensions of the test specimens and the neglect of size effects. R. G. Boiten, Holland

2838. Pauken, J. E., Statistical analysis of seaplane fatigue, *Aero/Space Engng.* **18,** 11, 63–67, Nov. 1959.

This study "stemmed from a number of failures which occurred in the bottom plating in the planing area of the hull, where high-frequency water pressure loadings are experienced during landing and take-off," but the "method of analytical treatment is applicable to many other aircraft and missile structures where material fatigue must be considered." From author's summary

2839. Fralich, R. W., Experimental investigation of effects of random loading on the fatigue life of notched-cantilever-beam specimens of 7075-T6 aluminum alloy, NASA Memo 4-12-59L, 22 pp., June 1959.

Fatigue results are presented for both constant-amplitude and random loading. These results are compared on the basis of time to failure, where an equivalent time to failure based on the natural period of vibration is used for the constant-amplitude tests. Fatigue failure occurs sooner for the random loading than for the constant-amplitude loading at the lower stress levels; however, at the higher stress levels the reverse condition is true. A theoretical result for random loading is also presented and compared with the experimental results. The theoretical result shows good agreement with experiment for low values of stress but underestimates the time to failure at the higher stresses.

From author's summary

2840. Clauss, F. J., Thermal fatigue of ductile materials: III—Behavior of crucible 422 steel, NASA TN D-69, 23 pp., Oct. 1959.

A study was made of the behavior of Crucible 422 steel in thermal fatigue and of the effect of constrained and free thermal cycling on the subsequent behavior in stress-rupture.

Specimens of Crucible 422 steel were alternately heated and cooled while constrained in a manner that prevented their free axial expansion and contraction, and the number of cycles to failure (cracking or fracture) was determined. The maximum cycle temperature (T_{max}) varied from 1000 to 1500 F, and the minimum cycle temperature was held constant at 200 F. Under these conditions the effect of T_{max} on the number of cycles to failure showed an abrupt change at a T_{max} of 1200 F. Cycling to T_{max} of 1200 F and above caused failures in less than 2000 cycles, while cycling to T_{max} below 1200 F did not cause any failures in less than 20,000 cycles. Considerable bulging of the specimens due to compressive creep occurred, however, at T_{max} of 1200 F and above.

Other specimens were removed from the thermal-fatigue apparatus before failure and subsequently tested in stress-rupture at 1100 F and 46,000 psi. Their behavior was compared with stress-rupture results for specimens subjected to identical temperature cycles but without constraint. Exposure to thermal fatigue or to thermal cycling alone in the absence of constraints significantly reduced the stress-rupture life.

Metallurgical changes caused by T_{max} were most significant in the thermal-fatigue behavior of Crucible 422 steel. During thermal cycling (constrained or free), the structure of tempered martensite undergoes further tempering and conversion to ferrite and spheroidized carbides, with an accompanying loss in hardness and stress-rupture strength. From author's summary

2841. Schjelderup, H. C., Accumulative fatigue damage caused by random loading, *J. Aero/Space Sci.* **26,** 6, 394-395 (Readers' Forum), June 1959.

2842. Kroll, Wilhelmina D., Aerodynamic heating and fatigue, NASA Memo 6-4-59W, 30 pp., June 1959.

A review of the physical conditions under which future airplanes will operate has been made and the necessity for considering fatigue in the design has been established. A survey of the literature shows what phases of elevated-temperature fatigue have been investigated. Other studies that would yield data of particular interest to the designer of aircraft structures are indicated. From author's summary

2843. White, D. J., Crossland, B., and Morrison, J. L. M., Effect of hydrostatic pressure on the direct stress fatigue strength of an alloy steel, *J. Mech. Engng. Sci.* **1,** 1, 39-49, June 1959.

Paper describes tests in which specimens are subjected to cyclically varying direct stress, that is, in 'push-pull' with additional tensile and compressive mean stress, both at atmospheric pressure and also while the material is subjected to ambient fluid pressure of the order 3000 atm (20 ton/in.^{2}); for this work a novel testing machine was developed.

The results of tests at atmospheric pressure are in good agreement with earlier tests and show that the range of direct stress leading to fatigue failure is a continuous function over the range of mean stress used. When fluid pressure of 20 ton/in.^{2} is superimposed on the stress system, the range of *reversed* stress required to cause fatigue failure is increased by a small, but definite, amount. For the tensile mean stress values investigated the fatigue limit appears to have been raised until it coincides with the range of stress required to cause "gross yielding" with a reduction in area *greater* than that which occurs in a static tension test at atmospheric pressure. For the compressive mean stress values investigated, fatigue failure has been entirely eliminated. From authors' summary

2844. Rudnitskii, N. M., On the determination of the fatigue strength of soft metals and alloys, *Indust. Lab.* **24,** 3, 370-371, May 1959. (Translation of *Zavod. Lab., USSR* **24,** 3, 331-333, Mar. 1958 by Instrument Society of America, Pittsburgh, Pa.)

2845. York, J. E., Hydro-fatigue test of a large cargo aircraft, *Aero/Space Engng.* **18,** 5, 44-47, 56, May 1959.

2846. Reed, E. C., and Viens, J. A., The influence of surface residual stress on fatigue limit of titanium, ASME Production Engng. Conf., Detroit, Mich., May 1959. Pap. 59-PROD-1, 4 pp.

Investigation of the effect of surface residual stress on the endurance limit of 6A1-4V titanium alloy shows that this effect is equal within experimental error to the residual stress divided by a constant. Results can be expressed by a simple equation. A value for the constant has been derived.

From authors' summary

2847. Stuiver, W., and Tomalin, P. F., The failure of tubes under combined external pressure and axial load, *Proc. Soc. Exp. Stress Anal.* **16,** 2, 39-48, 1959.

The relationship between external pressure and axial load at failure was investigated for tubes which fail by plastic buckling under external pressure alone. Two series of experiments were conducted to determine the critical loading conditions. The experimental techniques are described and the observations discussed. An attempt is made to correlate the results with the relevant formulas for elastic materials.

From authors' summary by J. Heyman, England

2848. Mylonas, C., Prestrain, size and residual stresses in static brittle-fracture initiation, *Welding J.* **38,** 10, 414s-424s, Oct. 1959.

The concept of exhaustion of ductility used in the explanation of the mechanism of static brittle-fracture initiation has led to the achievement of the first laboratory fractures of unwelded steel plates under central static loading at average net stress as low as 12% of virgin yield. The same concept and considerations of required existing ductility provide a rational approach for the explanation of prestrain and of size effect in brittle fracture.

Similarly they lead to a clear qualitative assessment of the varying influence of residual stresses and show that the usual localized residual stresses have little if any importance in normal structural steels. From author's summary

2849. Bykov, V. A., Plasticity and brittleness of structural steel as determined by biaxial tensile tests on notched specimens, *Indust. Lab.* **24**, 9, 1241–1244, Sept. 1959. (Translation of *Zavod. Lab., USSR* **24**, 9, 1116–1119, Sept. 1958 by Instrument Society of America, Pittsburgh, Pa.)

Three types of the fracture of steel are possible, corresponding to tough, partially tough, and brittle conditions at two critical temperatures; these fractures are obtained in biaxial tensile tests on flat notched specimens. Owing to the low limiting load and small absorption of energy, the brittle fracture is caused by an insignificant action. In the least favorable conditions with repeated deformation, the tough, shallow notches cause an instantaneous propagation of the brittle fracture at insignificant limiting loads. From author's summary

2850. Hahn, G. T., Owen, W. S., Averbach, B. L., and Cohen, M., Micromechanism of brittle fracture in a low-carbon steel, *Welding J.* **38**, 9, 367s–376s, Sept. 1959.

Authors present tensile data, elastic-limit measurements and metallographic observations of slip, twinning and microcracks, as well as standard Charpy data, for a low-carbon steel in a coarse- and a fine-grained condition. From authors' summary

2851. Davidson, T. E., Barton, C. S., Reiner, A. N., and Kendall, D. P., A new approach to the autofrettage of high strength gun tubes, IPM Project, Metal Working Section, Industrial Processes Branch, Research and Engineering Branch, Watervliet Arsenal, Watervliet, New York, ix + 69 pp., Apr. 1959.

The usual method of autofrettage for gun tubes utilizes hydraulic pressure applied directly to the bore in order to plastically deform the wall of the tube in such a manner as to produce favorable residual stress patterns. In this manner strength of the tube is effectively increased, providing many associated benefits. However, ultra-high hydraulic pressures are required to autofrettage high-strength steels since the pressure required to plastically deform the tube is directly proportional to the yield strength of the material.

To provide a new approach, an alternate method of autofrettage requiring reduced hydrostatic pressure is developed and described. This method consists of passing an oversized mandrel through the tube to plastically deform the walls of the tube. Three methods of forcing the mandrel are investigated, using specimens of nominal five-inch length and forty-inch length. Mechanical push swaging is used in the autofrettage of the short specimens. Pull swaging and hydraulic push swaging are used on the long specimens. All specimens were made from a modified 4340 steel, and heat treated to the various strengths involved.

A complete engineering analysis is made on the short specimens, using wall ratios ranging from 1.5 to 2.8, nominal yield strengths ranging from 90,000 psi to 180,000 psi, and nominal enlargements at the bore ranging from 1.0 to 5.0%. Such factors as percentage of enlargement and elastic recovery at the bore, the ratio of pressure required for pushing the mandrel to the yield strength of the material, the effect of various lubricants on the frictional forces involved, and the induced three-dimensional residual stresses are evaluated.

The induced residual stress pattern is studied using Sach's boring-out technique, and typical results are reported and discussed. Strains are recorded with electric-resistance strain gages, and the associated dynamic and static instrumentation is described. Results are presented in table and graph form.
From authors' summary

Experimental Stress Analysis

(See also Revs. 2766, 2816, 2846)

2852. Fessler, H., and Haines, D. J., Plasto-elastic stress distributions in lugs, *Aero. Quart.* **10**, 3, 230–246, Aug. 1959.

Stresses were determined by the photoelastic-reflection method which gives an immediate survey over the strain distribution by fringe patterns arising and proceeding with the load. Following the ascending and the descending loads elastic and plastic yielding can be distinguished. Semicircular-ended lugs were tested under axial load and the ratio (hole diameter/lug width) was varied. The results are evident but not at all presumptive.
P. P. Heusinger, Germany

2853. Thomson, R. A., The use of digital computers in the photoelastic solution of the general space problem by the shear-difference method, *Proc. Soc. Exp. Stress Anal.* **16**, 2, 11–16, 1959.

The shear difference method to determine stress components from three-dimensional photoelastic data by numerical integration is summarized. A program for an automatic digital computer to perform these calculations is described using block diagrams. Programmed for the IBM 650, the method checked well with hand computations (30 to 60 min per step); it required 1 min human time plus 10 sec computer time per step. A supplementary program to find principal stresses is described, requiring an additional 30 sec computer time per point.

Reviewer believes the program significantly increases the usefulness of the shear difference method, and that it may be used profitably even in two-dimensional analysis.
N. C. Lind, USA

2854. Johnsen, I., An optical method for studying buckling of plates, *Proc. Soc. Exp. Stress Anal.* **16**, 2, 145–152, 1959.

Models made of Perspex are illuminated by an extended, grid-shaped light source and loaded. The reflected image indicates the form and direction of the buckles. The buckling of the plate is influenced by the initial unevenness, which may also be studied in this way. C. Hoschl, Czechoslovakia

2855. Frocht, M. M., Landsberg, D., and Wang, B. C., The effect of gage current on strain measurements, *Proc. Soc. Exp. Stress Anal.* **16**, 2, 69–72, 1959.

2856. Lubahn, J. D., Comparison of methods of determining stress concentration factor, *Proc. Soc. Exp. Stress Anal.* **16**, 2, 139–144, 1959.

Resistance strain gage results are shown for a 25.4 times size steel model of a Charpy impact specimen. Transverse strains and Poisson's ratio of material were not measured. Stress concentration factor is calculated using photoelastic result to justify correction for strain gradient over gage length (latter equal to notch radius), thus demonstrating that resistance gages cannot provide stress concentration factor independently. Result agrees with calculated value; both less than photoelastic result.

Author states longitudinal strain to be equal at center and end of notch. Because plane stress must exist at end, assumption of plane strain at center implies minimum scatter of 10% of strain gage results if longitudinal stress is constant across section.

Reviewer believes: (1) Error in calculated result is due to discontinuity of curvature of actual straight-sided notch as well as failure to meet boundary conditions; (2) difference between stress distributions in hyperbolic and straight-sided notch may affect strain-gradient correction. H. Fessler, England

2857. Hu, L. W., Development of a triaxial stress testing machine and triaxial stress experiments, *Proc. Soc. Exp. Stress Anal.* **16**, 2, 27–38, 1959.

2858. McGonnagle, W. J., Renken, C. J., and Myers, R. G., Improved nondestructive testing by eddy-currents, *Electronics* **32,** 35, 42–43, Aug. 1959.

Method of measuring metal wall or plating thickness or detection of subsurface cracks and voids uses induced eddy currents. Variation of probe-to-specimen spacing is compensated by using two different induction frequencies.

From authors' summary

2859. Benson, R. W., and Raelson, V. J., Acoustoelasticity, *Prod. Engng.* **30,** 29, 56–59, July 1959.

These two researchers polarized high-frequency sound wave and made them do anything the photoelastic methods can do, and something more—check for residual stresses. Here's their first published account of how the method works, and of still newer developments now underway. From authors' summary

Material Test Techniques

(See also Revs. 2837, 2856, 3031, 3142, 3183)

Book—2860. L'Hermite, R., General methods of testing and control in the laboratory, Vol. 1, Geometrical and mechanical measurements [Methodes generales d'Essai et de Controle en Laboratoire. I. Mesures Geometriques et Mecaniques], Paris, Eyrolles, 1959, xii + 739 pp. 9700 F.

This is the first of a new series of books on laboratory testing and its bearing on the control of the quality of constructional materials. The subject of the volume is geometrical and mechanical measurements. The book begins with a chapter on laboratory organization.

Next comes a discussion of the place of statistics in the testing of materials and this is followed by a chapter on units. Consideration is then given to geometrical measurements, which include sieving and particle size analysis; there is also a useful section on surface roughness. Mechanical measurements come next and include methods for the determination of time, speed, mass and force. This chapter is followed by a long and detailed one on extensometry and this again by an even longer one on testing machines. The tests considered are those for tension, compression, bending, torsion, combined stress, impact, hardness, wear, elastic constants, internal friction and fatigue. There is also a section on the calibration of testing machines. Each chapter has a bibliography for more detailed reading and the book is provided with subject and author indexes.

The text is well illustrated with drawings and diagrams; many of the latter seem to have been specially drawn, using a simplified plan which is generally most effective but occasionally hard to follow. An unavoidable difficulty in a work of this kind is that its length makes it impossible for every part to be completely up to date. However, it presents a fairly well balanced picture of the subject and can be recommended as a useful reference book.

A. F. C. Brown, England

2861. Tsobkallo, S. O., Slavskii, G. N., and Chetyrkina, N. A., A new instrument for measuring the elastic modulus of sheet materials, *Measurement Techniques* no. 1, 27–31, Aug. 1959. (Translation of *Izmeritel'naia Tekhnika, USSR* no. 1, 24–27, Jan./Feb. 1958 by Instrument Society of America, Pittsburgh, Pa.)

Authors have developed an instrument to measure modulus of elasticity dynamically for thin (0.004 to 0.031 in.) and flexible sheet materials under controlled temperature conditions. A small oven encloses a cantilever-supported strip of material under test, which is deflected and allowed to vibrate freely, cutting a beam of light focused on a photoelectric pickup. Natural frequency of oscillation is measured using an electronic counter, and modulus of elasticity is computed based on its known relation to natural frequency of the fundamental mode of cantilevered specimens.

Authors state that elastic moduli were measured with this instrument to relative errors of 0.5–1.0%. No test data are given.

R. L. Sutherland, USA

2862. Thurlimann, B., and Eney, W. J., Modern installation for testing of large assemblies under static and fatigue loading, *Proc. Soc. Exp. Stress Anal.* **16,** 2, 81–96, 1959.

A modern installation has been made at Fritz Engineering Laboratory, Lehigh University, for testing large assemblies under static and fatigue loading. A description is given of a test bed to which are attached adjustable structural frames that enclose the full-size structure and the loading equipment. Loads up to 110,000 lbs per each of two hydraulic jacks and at rates of 250 or 500 cycles per minute can be applied. A few of the tests made are portrayed.

Two additional pieces of equipment are described. One is a 220,000-lb alternating stress testing machine, permitting tests at 250 or 500 cycles per minute on 40-in. long tension or compression specimens and bending specimens up to 55 in. in span. The other is a high-speed fatigue testing machine of 22,000-lb capacity for frequencies of 8,000 to 18,000 cycles per minute. Fluctuating and alternating load tests of small specimens under tension, bending or torsion permit a rapid determination of the *s-n* curve.

From authors' summary

2863. Zaiamyi, V. I., Effect of the shape of the cross-section of the specimen in static and in impact shear testing, *Indust. Lab.* **24,** 9, 1244–1247, Sept. 1959. (Translation of *Zavod. Lab., USSR* **24,** 9, 1119–1122, Sept. 1958 by Instrument Society of America, Pittsburgh, Pa.)

2864. Tomenko, Iu. S., Navrotskii, I. V., and Volchek, F. R., Calculation of impact energy in multiple impact tests, *Indust. Lab.* **24,** 9, 1247–1250, Sept. 1959. (Translation of *Zavod. Lab., USSR* **24,** 9, 1122–1125, Sept. 1958 by Instrument Society of America, Pittsburgh, Pa.)

2865. Ashkenazi, E. K., Dutov, B. P., and Rubinshtein, G. M., On the determination of the impact compression strength of timber, *Indust. Lab.* **24,** 9, 1251–1253, Sept. 1959. (Translation of *Zavod. Lab., USSR* **24,** 9, 1125–1128, Sept. 1958 by Instrument Society of America, Pittsburgh, Pa.)

2866. Bandyshev, B. A., Effect of mass of specimen on hardness values determined by dynamic methods, *Measurement Techniques* no. 2, 144–146, Aug. 1959. (Translation of *Izmeritel'naia Tekhnika, USSR* no. 2, 21–23, Mar./Apr. 1958 by Instrument Society of America, Pittsburgh, Pa.)

2867. Chernashkin, V. G., Gofner, A. M., and Sivriukova, M. A., On the question of assessing the quality of sheet steel by testing for impact strength, *Indust. Lab.* **24,** 9, 1237–1241, Sept. 1959. (Translation of *Zavod. Lab., USSR* **24,** 9, 1112–1116, Sept. 1958 by Instrument Society of America, Pittsburgh, Pa.)

2868. Grigorovich, V. K., On the determination of hardness by the scratching method, *Indust. Lab.* **24,** 8, 1124–1129, Sept. 1959. (Translation of *Zavod. Lab. USSR* **24,** 8, 1007–1013, Aug. 1958 by Instrument Society of America, Pittsburgh, Pa.)

Author's purpose is to correlate scratch hardness measurements with indentation hardness numbers. He shows analytically that work expended per unit volume of groove is directly proportional to the vertical load P per unit of projected area of the stylus in contact with the specimen. If the stylus is a square pyramid, such as the standard 136° indenter, moving along one diagonal, the scratch hardness expressed as $H_s = 4P/b$ (b = width of groove)

should correspond with the common indentation hardness number, H_{in}. Tests indicate that the exponent n, from $P = b^n$, ranges from 1.8 to 2.0, and that the ratio H_s/H_{in} ranges between 0.72 and 1.41 when the same indenter is used for both methods on a variety of materials. E. B. Shand, USA

2869. Pykhtin, Iu. A., Elimination of temperature error in working with thermo-compensated tensometers, *Measurement Techniques* no. 2, 147–149, Aug. 1959. (Translation of *Izmeritel'naia Tekhnika, USSR* no. 2, 23–25, Mar./Apr. 1958 by Instrument Society of America, Pittsburgh, Pa.)

Author has developed, tested and employed thermo-compensated tensometers made from unannealed constantan wire of 0.03-mm diameter and nichrome wire of 0.04-mm diameter. It is shown that errors due to uneven heating temperature distribution are present and author concludes that these errors can be minimized by situating the nichrome portion exactly at the center of the strain-sensitive grid. J. Rabinowicz, Israel

2870. Finnie, I., A tester for creep rupture under multiaxial stress, *Proc. Soc. Exp. Stress Anal.* **16,** 2, 49–54, 1959.

Literature on multiaxial creep-rupture tests is briefly reviewed, concluding that the maximum tensile stress controls the time to fracture. Apparatus is described in which three tubes may be tested by combinations of tension, compression, torsion and internal pressure at temperatures up to 500 F. Pressure is applied through a liquid while specimens are immersed in a liquid for temperature control. F. Forscher, USA

Properties of Engineering Materials

(See Revs. 2721, 2738, 2808, 2814, 2816, 2837, 2839, 2843, 2844, 2849, 2860, 2867, 2870, 3060, 3139)

Structures: Simple

(See also Revs. 2708, 2731, 2732, 2772, 2779, 2848, 2884)

Book—2871. Matheson, J. A. L., Hyperstatic structures, Vol. 1: An introduction to the theory of statically indeterminate structures, New York, Academic Press, Inc., 1959, xv + 474 pp. $15.50.

This treatise on statically indeterminate structures (author considers the term "hyperstatic structures" more exact) should prove of value as a reference for research workers and teachers of the subject. A glance at the table of contents shows that several new topics not met with in most existing texts, such as complementary energy, stability of frameworks, matrix methods, are covered in this volume. The author's critique of complementary energy and its relation to virtual work, plastic design methods and their limitations is both interesting and illuminating.

On the other hand, perhaps because of the vastness of the field, the treatment of the various topics is uneven. As an example, moment distribution methods for curved members is omitted while the application of this method for the case of combined axial and lateral loads is treated very briefly. As the author acknowledges the power and usefulness of moment distribution, these omissions are somewhat surprising. It is possible that a second volume of worked-out examples, promised by the author, will restore the balance. T. Wah, USA

Book—2872. Stussi, F., Design and computation of steel structures, Vol. 1, Fundamentals of steel structures [Entwurf und Berechnung von Stahlbauten, Erster Band, Grundlagen des Stahlbaues], Berlin, Springer-Verlag, 1958, ix + 577 pp. DM 55.50.

Engineers who wish to acquire knowledge that will enable them to attack new problems as they arise will find this book a very valuable addition to their library; at the same time the factual information and results (much of it published for the first time in book form) make it equally valuable as a reference book.

The present volume is the first part of a trilogy; the two others to come are *Steel buildings* and *Steel bridges*. The book is divided into 9 chapters (with subchapter headings in brackets): (1) General questions (Applications, Notable achievements and trends); (2) Steel as a construction material (Composition, Manufacture of steel, Rolled sections, Strength, deformation and safety, Corrosion and corrosion protection); (3) Connections (Riveting, Bolting, Welding); (4) Numerical solution of differential equations, (Analytical and numerical methods, Numerical integration and differentiation, Linear, second order, nonhomogeneous differential equations, Fourth order differential equations, Membrane equation, Disks and plates); (5) Bending and torsion of thin-walled slender bars (Fundamentals, Open sections, Box sections); (6) Stability problems (Buckling of columns, Torsional buckling and buckling of beams, Buckling of plates and tubes); (7) Vibrations of girders (Fundamentals, Free vibrations, Forced vibrations); (8) Design and dimensioning of construction elements (Solid web girders, Lattice girders, Supports and joints); Fabrication of structures (Workshop operations, Erection). As the chapter headings show, author planned to give a very comprehensive coverage; however reviewer believes that he achieved his aim very unevenly in different directions and that there are some very notable omissions. The mathematical parts dealing with stress analysis and structural mechanics contain a considerable amount of original material and do present most of the information which the designer is likely to look for in the book, whereas some of the descriptive sections are so scanty that their inclusion seems hardly justified (e.g. the effect of alloying elements on the properties of steel is covered in one page; the layout of a fabricating shop is described in three lines and a block-diagram; chapter 9 is compressed into 13 pages of which about 8 are taken up by illustrations). Only a brief controversial mention is made of limit (plastic) design; relaxation and iteration methods are omitted. Reviewer found no mention of brittle fracture and of shear lag, although this may be blamed on the absence of a subject index. In the preface author claims that an index is obviated by the copious "Table of contents" (approx. 160 entries); this seems to be hardly the case if information on fatigue strength of welded joints appears in the section titled "shrinkage stresses" and if buckling of elastically supported columns, battened and latticed columns are all treated under the heading "special cases."

However, in the balance the merits of the book far outweigh the shortcomings mentioned. The work on the numerical solution of differential equations should appeal to all structural engineers who are well-versed with relationships between loading and bending moments; it is clearly presented and well illustrated by fully worked examples throughout the book. The chapter on bending and torsion of thin-walled members contains a more detailed treatment than found in the average textbook on structural design. Buckling problems are brought within our grasp in the next chapter; examples illustrate the application of the theory to several problems that would have been beyond the reach of most engineers before the development of modern numerical methods. The same applies to many of the problems treated in the next chapter on vibrations. The chapters dealing with the design of connections and construction elements also contain much useful material that should help a rational approach to detail design.

Printing, clarity of illustrations and binding are of the high standard that we have come to expect from the publishers, Springer's.

G. Sved, Australia

2873. Pei, M. L., Matrix solution of beams with variable moments of inertia, *Proc. Amer. Soc. Civ. Engrs.* **85,** ST 8 (*J. Struct. Div.*), 1-14, Oct. 1959.

Simply supported beams with variable moments of inertia are divided into n equal intervals and the classical governing equations on bending moments and deflection are expressed in finite difference form. Matrix algebra is used for direct computation of bending moments, moment influence coefficients, deflections, and deflection influence coefficients. Method is particularly suited for digital computers. D. Frederick, USA

2874. White, A., Analysis of rigid frames by electronic computation, *Proc. Amer. Soc. Civ. Engrs.* **85,** ST 9 (*J. Struct. Div.*), 65-77, Nov. 1959.

Author describes a computer program which reduces the analysis of a variable section gabled rigid frame from a three-man-day desk calculator project to a twenty minute project for an engineer, computer personnel, and an IBM 650. He demonstrates that the output of computer programs may be printed out directly in the tabulated form of engineering reports, complete with explanatory headings and ready for immediate use or inclusion in a larger report.

Specific suggestions are listed for correlation of the combined efforts of an engineer and computer personnel in developing a computer program. From author's summary

2875. Huey, S. E., Fixed point method of moment design, *Proc. Amer. Soc. Civ. Engrs.* **85,** ST 9 (*J. Struct. Div.*), 31-52, Nov. 1959.

Paper presents a quick and simple method for finding the maximum moments in building frames. The data presented are for vertical loads on rectangular frames having members of constant section.

No new theory is involved. Certain subjects, such as sidesway and the effect of haunches on beams, are not considered.

From author's summary

2876. Brown, E. H., A theorem of maximum strain energy, *ASME Trans.* **81**E (*J. Appl. Mech.*), 1, 73-76, Mar. 1959.

A new theorem for elastic structures obeying Hooke's law is proved and enunciated as follows: If the strain energy can be expressed in terms of given external loads and the positions of points constrained to have no displacement, then the expression will have a maximum value when the positions are such as make the constraining forces zero. The theorem is generalized to allow a wider class of constraint, such as the attachment of a second, rigid structure to the elastic structure under analysis in such a way that the two have certain displacement components in common.

From author's summary by R. I. Prisicu, Roumania

2877. Raevskii, A. N., Calculation for the strength of a single-storied multi-spanned free frame with a stepped base by the method of the equation for one unknown (in Russian), Reports of the 16th Scientific Conference of the Instructional Staff of the Leningrad Engineering-Constr. Institute, Leningrad, 1958, 603-607; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 898.

An investigation is made on the frame described in the title. The positions of change of section of the bases (the steps) are all at one level, as is the case for the cross bars. It is assumed that the loss of strength in the frame being examined takes place at the maximum load for the crane, that is, at the moment when the cranes link up the bases on a level with the steps as though by hinged cross bracing of infinite rigidity. Thanks to this the equation for strength is made much more simple. The method of deformations is adopted. The angles of rotation of the upper joints of the frame and the linear transposition of the bases on a level with the steps and the cross bars are taken to be unknown values. The relation between the magnitudes of transposition for all the bases is taken to be identical. For the solution of the system of equations the method is adopted of the equation for one unknown, which manifests itself as the method of successive elimination of unknowns. In the author's view this is simpler than the method of deriving and disclosing determinants. No examples are given. The equation for the critical state contains two unknowns: the critical parameter $v_{ncr} = \sqrt{p_{ncr} b^3/EI_n}$ and the relation of linear transpositions. The minimum value for v_{ncr} is sought by the method of trial. For the determination of the critical load in the first approximation the proposal is to utilize a simplified formula giving mainly low values for the critical load (up to 10%).

G. M. Chuvikin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2878. Yu, Y.-Y., A new theory of elastic sandwich plates—one-dimensional case, AFOSR TN 58-896 (Polyt. Inst. Brooklyn, Dept. Mech. Engng.; ASTIA AD 204 133), 25 pp., Oct. 1958.

A generalized theory on isotropic elastic sandwich plates is derived from the theory of virtual work. Stress, strain, and displacement equations are given in general terms, considering the effects of transverse shear deformation and flexural rigidity of both the core and the faces of the sandwich plate. Inertia forces have also been included in the general equations, enabling author to attack the vibration problem for the one-dimensional plane-strain case. Results of the theory are applied to the problem of a cantilevered plate loaded at the free end by a line load, and to the problem of wave propagation in an infinite plate. Simpler methods for sandwich plates, as given by Mindlin, Reissner, Hoff, et al, can be deduced from author's final equation, when simplified accordingly. J. D. Marketos, USA

2879. Klein, G. K., Some new fields of application for the theory of boundary equilibrium (in Russian), *Trudi Mosk. In-ta Inzh. Gor. Str-va* no. 7, 9-27, 1957; *Ref. Zh. Mekh.* no. 10, 1958, Rev. 11496.

The study deals with the application of methods, worked out for the calculations for constructions made from ideal elastic-plastic materials, to new classes of problems. When determining the carrying capacity of intersecting beams, i.e. of three-dimensional constructions, consisting of two systems of mutually perpendicular continuous beams, joined at the points of intersection, the equilibrium of each beam is investigated under the action of an external load and reciprocal forces with beams in a perpendicular direction. The magnitude of the boundary load is found by means of the joint solutions of the equations for equilibrium and the equations expressing the (conditions of) equality of the deflection moments in sections where a plastic hinge is formed to the magnitude of the boundary moment. It is shown that in vertical load calculations for pile foundations, which are of small sensitivity to uneven settling, there may be three causes for the onset of the boundary condition: sharp settling of the pile (collapse into the soil), description of the material of the pile (onset of flow during compression), loss of strength of the pile in the soil. It is noted that in all these cases the onset of the boundary condition is linked with the increase of deformation of the pile, at the determined stage in its loading, without increase in the load, that is to say, the link between the load and the displacement in all three cases may be represented in the form of a diagram analogous to the diagram of the deformation of an ideal elastic-plastic body. Because of this piles are investigated as elements of construction made from ideal elastic-plastic material, and when calculating pile foundations the method of boundary equilibrium is employed. For the case where the carrying capacity of the foundation is being determined by the settlement of the piles into the soil, a calculation procedure is brought into use consisting of a calculation for the eccentrically loaded pile foundation and of a deduction for the relation of the determination of the settling of the pile foundations in the process of loading. The problem regarding the calculations for floating (pontoon) bridges is restricted to cases of centrally

hinged supports effected by the action of continuous systems of cables on the closed pontoons. The bond between the magnitude of the supporting reaction and the settlement of the closed pontoon is assumed to be linear up to the moment of the full submersion of the pontoon, after which the magnitude of the supporting reaction remains constant. As a result the assumption is made that the behavior of the pontoon is akin to that of an element of construction made from an ideal elastic-plastic material. Insofar as it is assumed that the material of the continuous systems of rods also appears to be an ideal elastic-plastic the method of calculation by the boundary equilibrium can be applied for the determination of the carrying capacity of a floating bridge. Examples of the calculations are given. The problem is solved of the determination of the pressure of ice floes on the ice-breakers on bridge-buttresses and at hydrotechnical installations. The field of ice floes is looked upon as an ideal plastic body, and the ice breakers as a rigid stamping machine. Author uses the known solution of the problem on the pressure of a rigid die on the peripheral surface of a plastic body under the action of the forces of friction, proportional to the normal pressure. A formula is submitted for the calculations of the magnitude of the maximum pressure of the ice on ice breakers of different forms.

Yu. A. Rakovshchik
Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2880. Krenchel, H., Influence of the concrete tensile stresses on the stress distribution and deformation of reinforced concrete (in English), *Ingenioren* **3**, 4, 119–123, Dec. 1959.

As a consequence of the tensile stresses in the concrete, the stress distribution in a reinforced-concrete structure is somewhat different from what is normally assumed. The difference is particularly great before the formation of cracks, but the effect is still apparent for considerable higher loads.

In present paper a more correct calculation of the internal stress distribution has been made. This calculation shows the development of the various functions in relation to the development of the cracks. It is hereby possible to explain some of the apparent pecularities which regularly appear in laboratory investigations on reinforced concrete. From author's summary

2881. Rodriguez, J. J., Bianchini, A. C., Viest, I. M., and Kesler, C. E., Shear strength of two-span continuous reinforced concrete beams, *J. Amer. Concr. Inst.* **30**, 10, 1089–1130, Apr. 1959.

Fifty-two continuous reinforced-concrete beams were tested under concentrated loads and the results analyzed in an effort to determine the following: (1) effect of continuity on the shear strength of statically indeterminate members, (2) contribution of web reinforcement to shear strength, and (3) to establish the minimum amount of web reinforcement required to prevent shear failures. The following variables were included: type of loading, length of negative moment longitudinal reinforcement, percentage of web reinforcement, and grade of longitudinal reinforcement.

Fifteen beams were designed with no web reinforcement, 13 beams had the amount of web reinforcement required by the 1951 ACI Code, and 24 beams were designed with more web reinforcement than required by the ACI Code.

An analysis of the test results indicated good agreement with the calculated values for the loads at diagonal tension cracking, shear compression failure, and flexural failure, as computed with the aid of existing mathematical expressions developed from tests of simple and restrained beams. When the amount of web reinforcement was determined by equating the formulas for maximum flexural and maximum shear loads, it was found to be more than was necessary. From authors' summary

2882. Windels, R., Redistribution of stresses in reinforced concrete frames due to creep and shrinkage, Parts I and II (in German), *Beton u. Stahlbeton* **51**, 8, 179–183, Aug. 1956; **51**, 9, 204–209, Sept. 1956.

Representing the concrete by a linear Maxwell body with time-dependent viscosity, plasticity, and shrinkage, an attempt is made to analyze the redistribution of stresses between the concrete and the steel within the sections, as well as the redistribution, of moments and forces over statically determinate and indeterminate structures resulting from the effects of creep and shrinkage. The resulting system of two linear differential equations with variable coefficients for the corrections to the elastic moments and normal forces is solved under a number of simplifying assumptions, implications of which are, however, not sufficiently clarified. Particularly the assumption of a constant ratio n of the elastic moduli of steel and concrete does not seem acceptable.

The results are presented in the form of several nomographs. Since the procedure is not illustrated even by a single example nor is any attempt made to estimate the parameters appearing in the equations, the significance of the results can not be evaluated.
A. M. Freudenthal, USA

2883. Giannelli, G., Ultimate strength design of concrete sections eccentrically loaded (in Italian), *G. Gen. Civ.* **96**, 12, 828–836, Dec. 1958.

Paper is devoted to the discussion of the proposed ultimate design specifications to be introduced in Italian design practice. Attention is focused on the ultimate strength of rectangular members subjected to combined bending and axial load. Because no particular ultimate strength equations are recommended, author derives formulas concerning the mentioned case. The following basic assumptions are introduced: (1) The diagram of compressive concrete stress is assumed to be a trapezoid; (2) plane sections normal to the axis remain plane after bending; (3) tensile strength in concrete is neglected; (4) maximum fiber stress is assumed to be 80% of the cube strength; (5) stress in tensile and compressive reinforcement is assumed not to exceed the yield point; (6) maximum steel strain and maximum concrete strain in flexure are assumed to be known.

Using the equilibrium equations, a set of relationships is derived. The following particular cases are considered: (a) Concrete failure, steel stress below yield point; (b) concrete failure, steel stress at the yield point; (c) steel failure; (d) balance design. The relationships derived in the case of balance design are plotted in a graph. C. A. Sciammarella, USA

Structures: Composite

(See also Revs. 2731, 2750, 2802, 2824, 2827, 2882, 3135, 3139)

2884. Kaufman, S., and Glomb, J., Some prestressing problems of plate bridges (in English), *Bull. Acad. Polonaise Sci.* **7**, 5, 353–358, 1959.

The moment in the longitudinal direction of a slab (plate) bridge due to a concentrated load occupying various positions at midspan will be maximum when the load is applied at either longitudinal edge and minimum when applied at the center of the slab. This variation of moment can be accommodated (1) by suitable layout of longitudinal prestressing or (2) by tracing the transverse cables in such a way as to obtain uniform distribution of longitudinal prestressing. The second case is considered in this paper. Equations for determining the prestressing forces and eccentricity of the transverse cables are derived and the mathematics is fairly simple to follow. K.-H. Chu, USA

2885. Baus, R., and Massonnet, C., Distribution of loads by the slab in two-girder bridges (in French), *Bull. Centre Etudes*

Rech. d'Essais Scient. Constr. Genie Civ. et d'Hydraul. Fluviale **9**, 21–61, 1957.

In normal practice, girders supporting a slab are analyzed as if the loads transmitted by the slab were concentrated. The authors consider the slab as simply supported on the girders and abutments, taking into account (a) the contribution of the slab to the bending stiffness, and (b) the longitudinal distribution of the load applied to the girders. In the analysis, the actual bridge is replaced by a bridge with interior beams of equal stiffness, with additional reactions from the edge beams. Using principle of superposition, relationships between a slab simply supported on four edges and a slab free on two edges are obtained. Using Fourier series expansion for the loads, influence surfaces for design quantities (shears and moments) are obtained. The results are compared with the conventional analysis for the case of a uniformly distributed load, indicating considerable reduction of effects in some cases. In the reviewer's opinion, this reduction would be considerably increased if the actual stiffness of the girders were used rather than the infinite stiffness assumed by the authors.

S. J. Fenves, USA

2886. Massonnet, C., Practical design of multiple girder bridges taking torsional rigidity into account (in French), R.C.e Pubblicazioni del Corso di Perfezionamento per le Costruzioni in Cemento Armato, Milan, Politecnico, **8**, 3–40, 1958.

Grid work systems with and without torsion rigidity are studied.

For systems without torsion rigidity, analogy with the problem of beams on elastic foundation is shown and used. Practical expressions obtained for sinusoidal longitudinal loading may, in most cases, be directly employed, but their generalization for any other distribution is also presented.

For systems with torsion rigidity, a special rigidity parameter is introduced and its simplified computation indicated. Interpolation formulas are presented to transform the tabulated coefficients (that allow computation of longitudinal, transverse and twisting moments for systems without or with complete rigidity) into a function of torsion rigidity parameter.

Good agreement is obtained between theoretical results and experimental tests of bridges in Belgium and models in England. References to further progress in the study of bias bridges are given.

Paper summarizes author's preliminary studies on the subject.

F. Borges, Portugal

2887. Schjodt, R., Polygonal shape simplifies pipe prestressing, *Civ. Engng.* **29**, 4, 58–59, Apr. 1959.

2888. Argyris, J. H., and Kelsey, S., Note on the theory of aircraft structural analysis (in English), *Z. Flugwiss.* **7**, 3, 73–77, Mar. 1959.

The paper discusses some important aspects of the matrix theory of aircraft structures in the light of the recent contribution by B. Langefors and the work of the present writers. On the duality between the force and displacement methods of analysis, it is stressed that there are corresponding dual methods of idealization of the structure, and certain advantages and simplifications follow, for example, from the use of a kinematic idealization in the displacement method. The treatment of cut-outs and modifications is also discussed and the virtues emphasized of using matrix programming for the electronic computer so as to secure a close integration between analysis and computation with the resulting simplification and standardization of the complete procedure.

The methods dealt with do not require the concept of strain energy for their foundation, but the authors are strongly of the view that only simple physical arguments, in matrix form, are required not merely to give the theory its simplest and most elegant form but also its most general expression.

From authors' summary

2889. Rebeski, H., Purpose and construction of a prestressed and metal-bonded wing surface used on the Blume 502 aeroplane (in German), Jahrbuch Wissenschaft. Gesellsch. Luftfahrt, 1958, 213–217.

After a brief reference to the influence of wing loading on the principle of structure, the possibilities of stiffening thin wing panels are discussed. In order to eliminate buckling of unstiffened skin, prestressing is applied. For improving the surface quality, the thin skin is attached to the ribs by metal bonding. The stress distribution and structural details of the prestressed skin are discussed. The author gives a brief survey of the cost of production and of the possibilities for repair.

From author's summary

2890. Dickey, F. L., and Knipp, G. H., Sealed cabin reliability as related to structure and internal atmosphere, *ARS J.* **29**, 9, 656–661, Sept. 1959.

This paper considers the advantages to the crew of an optimum internal atmosphere and pressure and the effects on a sealed cabin structure. The reliability of the cabin and its resistance to fast fracture are discussed and shown to be essentially constant for various internal pressures with proper design. Certain safety advantages of a cabin designed for high pressure are pointed out; for example, a greater resistance to meteoroid penetration and a longer decompression time should a penetration occur. Means of increasing the time of decompression to permit effective emergency action are discussed, and the need for complete reliability of the sealed cabin system is emphasized.

From authors' summary

2891. Szilard, R., Structures for the moon, *Civ. Engng.* **29**, 10, 46–49, Oct. 1959.

2892. Corlett, A. V., and Emery, C. L., Design of a functional structure in or on rock, *Engng. J., Montreal* **42**, 4, 86–92, Apr. 1959.

Machine Elements and Machine Design

(See also Revs. 2773, 2852)

2893. Johnson, R. C., A simple numerical method for dynamic analysis and design of flexible cam mechanisms, *Mach. Design* **31**, 18, 140–145, Sept. 1959.

An analytical procedure, using finite differences, is described to find the transient vibrational response of a cam follower in terms of acceleration resulting from the driving action of the cam. The spring action between the follower mass and the cam is due to elastic deformation of the region of contact. Procedure is illustrated by an example for the cases when the follower mass is not loaded, and when it is spring loaded.

A. H. Church, USA

2894. Freudenstein, F., Harmonic analysis of crank-and-rocker mechanisms, with application, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 673–675 (Brief Notes), Dec. 1959.

For uniform driving-crank rotation, author's derivations allow (a) calculation of overtone amplitudes in the oscillation of the output link and (b) optimization of linkage proportions for high-speed operation for given range or pressure angle.

Reviewer believes that author has created a valuable new design tool.

G. N. Sandor, USA

Fastening and Joining Methods

(See Rev. 2708)

Rheology

(See also Revs. 2730, 2781, 2906, 3207)

2895. Tomita, Y., On the fundamental formula of non-Newtonian flow, *Bull. JSME* **2,** 7, 469–474, Aug. 1959.

A generalization of the Navier-Stokes equations is proposed for non-Newtonian fluids in which the stress is proportional to a power n of the rate of strain. As the equations are extremely difficult to solve when n is not an integer a variational method is proposed. It is shown that the principle of minimum energy dissipation is equivalent to the equations of motion with the inertial terms neglected when the external forces are derived from a potential. The method is applied to flow past a sphere and the drag coefficient is computed as a function of the exponent in the stress relation. For $n = 1$ the result is 3.7% higher than the well-known Stokes expression. W. Squire, USA

2896. Calderbank, P. H., and Moo-Young, M. B., The prediction of power consumption in the agitation of non-Newtonian fluids, *Trans. Instn. Chem. Engrs.* **37,** 1, 26–33, Feb. 1959.

Hydraulics

(See also Revs. 2680, 2690, 2691, 2910, 2928, 3052, 3163)

Book—2897. Volk, W., Valves for pipe lines [Absperrorgane in Rohrleitungen], Berlin, Springer-Verlag, 1959, vii + 178 pp. DM 25.50.

This book, newest of a series of monographs of engineering design (K. Kollmann, Editor), published by the Springer Publishing Company, contains a comprehensive and detailed treatment of operating analyses and design calculations of large valves for hydraulic pipe systems of turbine and pump installations. A chapter is devoted to each of the major types of valves, namely gate-, ring-, throttle-, check-, and air vent valves. Several of the many solutions of design problems pertaining to these valves are of wider significance, such as the examples of streamlining of valve passages in order to minimize the pressure loss, the calculation of hydrodynamic forces acting upon shutoff devices and of the operating and control forces related thereto, and the stress analysis of valve casings subjected to hydrostatic pressure. Special sections are devoted to problems of branching and distribution systems, of pressure surges in piping, of throttle control of pumps. The extensive list of literature serves as a guide to the original sources of specialized information. A wealth of examples is given of designs executed by German and Swiss firms, both of complete valves and of essential details. J. R. Weske, USA

2898. Katsuhara, T., Influences of roughness of inner surface of pipe upon pressure drop due to friction in two-phase flow, *Bull. JSME* **2,** 7, 439–445, Aug. 1959.

An empirical formula is obtained for the flow of water-air mixture in pipes with artificial roughnesses.

F. R. Hama, USA

Book—2899. Elevatorski, E. A., Hydraulic energy dissipators, New York, McGraw-Hill Book Co., Inc., 1959, xiii + 214 pp. $10.

Neatly edited and perfectly illustrated book belongs to the renowned series "Engineering Societies Monographs." Hydraulic engineers designing spillways and stilling basins will appreciate this useful tool. The part of hydraulics dealing with rapidly varying nonuniform flow, although complex and difficult for a practical engineer is particularly well prepared and presented. Author limited the theoretical part to simplest derivations and oversimplified some formulas. He neglected the energy and momentum correcting factors, assuming a uniform velocity distribution and reducing both factors to unity. This is incorrect, particularly in the hydraulic jump, where these factors must be much larger, sometimes as high as 3 or 4. Careful investigators, e.g., Bazin, applied energy correction factor for weirs equal to 2. Author gives a rather complex derivation for the critical depth in a trapezoidal channel, ending with a nomogram suitable for English system of units only. There are several universal and easier methods known in the literature. S. Kolupaila, USA

2900. Ellsworth, W. M., Model-prototype relations in the study of cable-towed body systems, Proceedings, Seventh Hydraulics Conference, Iowa Institute of Hydraulic Research, June 16–18, 1958; Iowa City, Iowa, State Univ. of Iowa, 1959, 245–271.

Within the restrictions imposed by military security the paper surveys problems and procedures associated with the design of cable-towed body systems for under-water devices. Author has aimed his discussion toward the non-specialist reader. He has succeeded in giving a concise and readable account of current design practice and of some important problems touching upon cable-towed bodies which are as yet unsolved. Particular items discussed in the paper concern the hydrodynamic characteristics of cables, the evaluation of drag, static and dynamic stability of towed bodies, model-to-prototype-scale effects on forces and moments, towing characteristics of complete systems together with the effects of towing platform motion; and the applicability of model test techniques in the solution of design problems. Finally, an attempt is made to assess the present status and future prospects for studies upon topics such as overall equations of motion for towed-body systems, the need for hydrodynamic data on systematic series of bodies, the use of cable fairing to reduce vortex shedding, and the value of and the difficulties connected with full-scale testing.

The intended scope of this paper does not permit very detailed discussions of any of the above topics. However, the reader with a particular design problem should find that many of the details missing from the present paper are more fully set forth in the various references selected by the author.

B. R. Parkin, USA

2901. Garner, F. H., and Haycock, P. J., Circulation in liquid drops, *Proc. Roy. Soc. Lond. (A)* **252,** 1271, 457–475, Oct. 1959.

Internal motion of liquid droplets is significant in various transport processes with the surrounding medium. Study shows that both Hadamard (viscous motion) and Hill (potential motion) vortex models apply to the internal motion, but the former gives a better description for external motion in the Stokesian regime and the latter for higher Reynolds numbers. The critical Reynolds number at which internal vortices begin to form and the resultant circulation depends on viscosity, impurities, and polarities of component molecules in addition to interfacial tension as predicted by Bond and Newton. Experimental work includes study of cinephotographs of individual drops containing aluminum particles up to Reynolds number of 1000; these drops are in general nonspherical and oscillate about their centers and the axes of motion. Circulation was observed in drops with radius down to 0.08 cm. This paper represents a rather gratifying effort toward understanding the system. It forms a logical basis for the correlation of internal motion to mass transport and stability of droplet sizes. Consideration of oscillation of liquid drops made by Chandrasekhar [*Proc. London Math. Soc.* (3), 9, 141–149, 1959] may refine the present case.

S. L. Soo, USA

2902. Young, N. O., Goldstein, J. S., and Block, M. J., The motion of bubbles in a vertical temperature gradient, *J. Fluid Mech.* **6,** 3, 350–356, Oct. 1959.

It has been observed experimentally that small bubbles in pure liquids can be held stationary or driven downward by means of a sufficiently strong negative temperature gradient in the vertical direction. This effect is demonstrated to be due to the stresses resulting from the thermal variation of surface tension at the bubble surface. The flow field within and around the bubble is derived, and an expression for the magnitude of the temperature gradient required to hold the bubble stationary is obtained. This expression is verified experimentally.

From authors' summary by T. Hayashi, Japan

2903. Yevdjevich, V. M., Analytical integration of the differential equation for water storage, *J. Res., Nat. Bur. Stands.* **63** B (*Mathematics and Mathematical Physics*), 1, 43–52, July/Sept. 1959.

Paper concerns the analytical integration of the storage differential equation [1] $P - Q = dS/dt$ (where P is the inflow, S the storage volume, Q the outflow, and t the time) for those cases for which the storage function, the outflow rating curves, and the inflow hydrograph can be entirely or partly expressed by simple relations which make equation [1] integrable. If the storage-outflow discharge relation $S = f(Q)$ is expressed under the form of a power function, $S = a(Q/b)^{m/r}$ (where a and m are coefficients to be determined from data of storage function, while b and r are coefficients depending only on boundary conditions and on type of flow), equation [1] becomes [2] $y' - cPy^2 - cy^k = 0$ (where $c = b^{(m/r)}/a$ and $k = 2 - r/m$). The analytical solutions of this equation for $P = 0$ and $P = \text{const}$, and certain $P = f(t)$ are given for the integrable cases. The application of results is discussed at the end of the paper. D. Gh. Ionescu, Roumania

2904. Dumitrescu, D., Ionescu, V., and Iancu, C., Theoretical and experimental contributions to the study of flows over spillways (in Roumanian), *Studii Si Cercetari Mecan. Appl.* **9,** 3, 595–624, 1958.

The relaxation method is applied to the study of flows over sharp-edged spillways and over those with large threshold at various Froude numbers. For each particular case, the stream function values are calculated and the flow patterns are presented. The same cases are experimentally investigated and results show good agreement with the theory. D. Gh. Ionescu, Roumania

2905. Dumitrescu, D., and Ionescu, V., Numerical methods for studying flows over spillways (in Roumanian), *Acad. Republ. Pop. Romine, Comun.* **8,** 4, 387–393, 1958.

A summary of the theoretical results obtained in the paper of the preceding review. D. Gh. Ionescu, Roumania

Incompressible Flow

(See also Revs. 2895, 2901, 2924, 2927, 2957, 2991, 3003, 3014, 3015, 3075, 3083, 3086, 3106)

2906. Gaydon, F. A., and Nuttall, H., Viscous flow through tubes of multiply connected cross sections, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 573–576, Dec. 1959.

Rectilinear, incompressible, steady, viscous flow is described by a Poisson equation. Authors use Green's theorem plus a Schwarz inequality to establish both upper and lower bounds for volume flow rate through an arbitrary (multiply-connected) channel. Two specific examples, square and hexagonal tubes with round cores, show gaps of less than 2% between the two bounds.

S. Corrsin, USA

2907. Gibbings, J. C., The design of an annular entry to a circular duct, *Aero. Quart.* **10,** 4, 361–372, Nov. 1959.

An axisymmetric annular entry into a circular duct is designed so that the velocity gradients at the wall are favorable to the development of the boundary-layer flow. As a first step the accelerating flow around a two-dimensional 90° duct bend with favorable gradients was obtained. This shape was modified and the axisymmetric flow pattern through it obtained by a combination of electrical analog and relaxation methods and then checked by experiment. The favorable gradients were retained in the axisymmetric flow.

From author's summary by E. H. Wissler, USA

2908. Sullivan, R. D., A two-cell vortex solution of the Navier-Stokes equations, *J. Aero/Space Sci.* **26,** 11, 767–768 (Readers' Forum), Nov. 1959.

2909. Weissberg, H. L., Laminar flow in the entrance region of a porous pipe, *Physics of Fluids* **2,** 5, 510–516, Sept./Oct. 1959.

Author considers case where similarity of velocity profiles is not an imposed condition. The equation of motion is simplified by neglecting terms involving second and higher inverse powers of the pipe flow Reynolds number. An approximate solution is given in terms of a polynomial which is required to have some important properties of the desired solution. Velocity profiles, pressure distributions, and wall velocity gradients are presented for wall injection and suction when the inlet velocity profile is parabolic. Flat inlet velocity profiles cannot be considered with the given approximate solution. Nonsimilar solutions indicate the onset of a separation profile and then reverse flow at the wall in suction Reynolds number range which agrees well with other numerical results. For wall injection or sufficiently small suction rates, solution approaches similarity solutions, corresponding to fully developed flow, found by other methods.

T. C. Adamson, Jr., USA

2910. Karas, K., Steady laminar flow through channels of elliptic cross section in the case of constant pressure or constant pressure distribution (in German), *Ing.-Arch.* **28,** 117–153, Mar. 1959.

The pipes are either horizontal or vertical and are completely filled with liquid. The deflection of a membrane stretched over the elliptic pipe cross section and the velocity distribution for laminar flow through the pipe are governed by similar Poisson equations. This membrane analogy is developed and results for several examples are presented.

G. E. Nitzberg, USA

2911. Tamada, K., and Fujikawa, H., The steady flow of viscous fluid at low Reynolds numbers passing obliquely through a plane grid made of equal parallel circular cylinders, *J. Phys. Soc., Japan* **14,** 2, 202–216, Feb. 1959.

Using Oseen's equations, the problem is reduced to solution of an infinite set of algebraic equations. When Reynolds number based on cylinder radius is small, flow deflects toward grid normal, ratio of normal drag to normal velocity becomes independent of incidence angle, and tangential drag goes to zero.

A. C. Pipkin, USA

2912. Nechaev, S. V., The flow about two circles (in Russian), *Trudi Kazansk. Aviats. In-ta* no. 35, 21–35, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 329.

The problems on the longitudinal and transverse flow about two circles without any circulation are solved in approximate form. The flow of two dipoles is imposed on the basic flow; each of the dipoles is located within one of the circles. The positions of these dipoles and their moments are selected approximately. In the case of a flow about circles with a circulation an addition is made of a complex potential having the form of

$$W = \frac{\Gamma_1}{2\pi i} \ln z + \frac{\Gamma_2}{2\pi i} \ln (z - t)$$

to the obtained complex potential of the longitudinal flow about two circles with centers at points $z = 0$ and $z = t$.

M. I. Gurevich

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2913. Payne, L. E., and Pell, W. H., The Stokes flow problem for a class of axially symmetric bodies, AFOSR TN 58-523 (Nat. Bur. Stands. Rep. 6372; ASTIA AD 158 336), 35 pp., Apr. 1959.

Assuming that the Reynolds number of the incompressible flow is very small, authors simplify the Navier-Stokes equations in the well-known way; the deduced equation for stream function is solved with the aid of the generalized axially symmetric potential theory [see A. Weinstein, *Trans. Amer. Math. Soc.* **63**, 342-354, 1948]. The paper also presents the expression for drag. Numerical results are given for lens-shaped bodies, namely for a hemisphere, for a symmetrical (bi-convex) lens, for a spherical cap, and for a pair of separated spheres.

M. Ruzicka, Czechoslovakia

2914. Kanwal, R. P., Slow rotatory motion of a circular disk about one of its diameters in a viscous fluid, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 485-487, Dec. 1959.

Author proposes to solve for velocity components, pressure and couple produced when a rigid thin disk is rotated about a diameter in a viscous fluid. This is an unsteady flow but author omits the acceleration term, in addition to second-order terms, from the Navier-Stokes equations. Therefore the problem actually solved (and to which the elastostatic analogy considered by the author applies) is for steady viscous flow about a *stationary* thin disk with prescribed normal velocity boundary conditions. Reviewer believes that, *in the problem solved*, author's reservations about zero shear stresses in the plane of the disk are unnecessary; not only are these shear stresses zero, but this may be taken as alternative equivalent boundary condition. R. L. Curl, USA

2915. Woronetz, K., On the quaternionic potential of a fluid three-dimensional motion (in Serbian), Scientific Works of the Faculty of Mechanical Engineering, Belgrade, 1956/58, 125-131.

By using authors results [see Rev. 2927 this issue], obtained by interpreting the Abilimovitch vector, which constitutes a new variant of the functions also considered by R. Fueter, N. Frechet, Gr. Moisil and M. Misicu, author obtains a class of three-dimensional irrotational motions, and in particular the flow in two different planes with a common rotation axis.

M. Misicu, Roumania

2916. Morgan, P. G., The coefficient of contraction in the flow through perforated plates, *J. Roy. Aero. Soc.* **63**, 588, 723-724 (Tech. Notes), Dec. 1959.

2917. Breslin, J. P., and Skalak, R., Exploratory study of ventilated flows about yawed surface-piercing struts, NASA Memo 2-23-59W, 65 pp., Apr. 1959.

Reported herein are the results of observations and measurements made in connection with a study of the phenomenon of the development of atmosphere-connected cavities about surface-piercing struts. Conditions for the existence of such ventilated flows which have been derived from the experimental data are presented. In addition, certain broad conclusions pertinent to model testing and full-scale design are reached.

From authors' summary

2918. Babalyan, G. A., Motion of a two-phase flow in the clearance between two bodies with rubbing surfaces (in Russian), *Trudi Azerb. N.-i. In-ta po Dobyche Nefti* no. 6, 81-86, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 620.

Some ideas are put forward regarding leakages through the clearance between the plunger and the bushing when pumping up a mixture of two liquids, particularly water-petroleum, by a deep-set pump. Basing his concepts on the analogy between motion in a clearance and motion in a porous medium and on personal investigations on the mechanism of petroleum extraction from oil-bearing strata, author arrives at several conclusions of a qualitative nature concerning the influence on the magnitude of the leakage of the relation of the contents of the two liquids in the mixture and the activity of the petroleum. V. A. Arkhangelskii

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2919. Hachemeister, C. A., The exact solution of Borda's mouthpiece in two dimensions, *Quart. Appl. Math.* **17**, 3, 299-304, Oct. 1959.

The two-dimensional Borda mouthpiece consists of two parallel plates which extend back into the fluid from the edges of an infinely long slit in a reservoir. A fluid jet discharges out of the slit from between the parallel plates. The well-known solution for the jet configuration assumes that the parallel walls of the mouthpiece extend far back into the reservoir. This paper treats the finite Borda mouthpiece which extends only a finite distance back into the fluid. The potential flow solution, which is obtained by conformal mapping, yields the characteristics of the discharging jet. The jet velocity and contraction coefficient are given as a function of the ratio of mouthpiece length to the width of discharge gap. When this ratio is large, the contraction coefficient goes to 0.5, which is the value for the semi-infinite mouthpiece. When the ratio goes to zero, the discharge coefficient becomes $1/(1 + 2/\pi)$, which is the value for discharge through a slit.

R. Siegel, USA

2920. Lindley, B. C., Pressure loss data for crimped metal strip matrices, *J. Roy. Aero. Soc.* **63**, 586, 597-602 (Tech. Notes), Oct. 1959.

2921. Pris, M. R., Hyperbolic cooling tower (in French), *Ann. Inst. Tech. Bât. Trav. Publics* **12**, 134, 147-167, Feb. 1959.

Measurements of drag as well as of wind pressures were made on a 1/7000 scale model of a hyperbolic cooling tower at the Eiffel Aerodynamic Laboratory. The model did not include a water distribution system. The effect of surface roughness on wind pressures was taken into account as well as the effect of similitude which approaches zero. Certain internal pressures were also measured and values were obtained for the strength of support columns. From author's summary

2922. Rietema, K., and Krajenbrink, H. J., Theoretical derivation of tangential velocity profiles in a flat vortex chamber—influence of turbulence and wall friction, *Appl. Sci. Res.* (*A*) **8**, 2/3, 177-197, 1959.

Interesting paper shows results of a theoretical investigation which are of practical value. The tangential-velocity distribution has been expressed in terms of the parameter $\lambda = -u_0 R/(\nu + \epsilon)$, where U_0 is radial velocity at the outer radius R of the chamber, ν and ϵ are the kinematic viscosity and kinematic eddy viscosity (assumed constant). For $\lambda > 10$ the tangential-velocity distribution is nearly hyperbolic, for $\lambda < 1$ this velocity decreases uniformly toward the center. The effect of wall friction has been taken into account only for the tangential-velocity, which then shows a non-uniform axial distribution. Inconsistent with it is the assumption of a uniform axial distribution of the radial velocity; wall friction has been neglected here, as are secondary flows. Paper is valuable in that it gives an insight into the effect of turbulence on the

tangential-velocity and pressure distribution (pressure drop). However, it does not prove that there is a constant eddy-viscosity and that there are no secondary flows.

J. O. Hinze, Holland

Compressible Flow (Continuum and Noncontinuum Flow)

(See also Revs. 2842, 2915, 2958, 2967, 2969, 2970, 2971, 2984, 2988, 2999, 3004, 3005, 3015, 3018, 3022, 3025, 3030, 3058, 3059, 3065, 3109, 3131, 3142, 3158, 3188)

2923. Chang, C. C., and Lundgren, T. S., Airfoil in a sonic shear flow jet: a mixed boundary value problem for the generalized Tricomi equation, *Quart. Appl. Math.* **17**, 4, 375–392, Jan. 1960.

Paper deals with small perturbations in a nonuniform two-dimensional inviscid compressible flow. It transforms the well-known linearized differential equation of gasdynamics into Tricomi's generalized equation and then, applying Wiener-Hopf technique, develops general solutions for several specific conditions. Results obtained are then applied to flat-plate and Chaplygin-type profiles, for which the writer develops analytical methods of calculation of pressure coefficient, lift coefficient and pressure center, with numerical examples and graphical illustrations. The work is mainly mathematical.

G. A. Tokaty, USA

2924. Wasserman, R. H., Helical fluid flows, *Quart. Appl. Math.* **17**, 4, 443–445, Jan. 1960.

Paper considers all steady incompressible helical flows and all steady compressible helical flows with entropy (S) constant along the streamlines. From the governing equations it is deduced that either (a) the velocity magnitude (q), pressure (p) and density (ρ) are constant along the streamlines or (b) $q^2 = \partial p/\partial\rho$ and $p = B(S) - A(S)/\rho$, where the functions $A(S)$ and $B(S)$ are restricted only by the condition $A(S) > 0$. Certain features of the two resulting classes of flow are briefly discussed and some general properties of flows of case (a) are summarized.

A. D. Young, England

2925. Morgan, P. G., High speed flow through wire gauzes, *J. Roy. Aero. Soc.* **63**, 584, 474–475 (Tech. Notes), Aug. 1959.

2926. Ray, M., Note on the variation of temperature due to small steady disturbances in a compressible flow, *Bull. Calcutta Math. Soc.* **50**, 3, 150–154, Sept. 1958.

The purpose of present paper is to remove certain contradictions found in a previous publication [AMR **7** (1954), Rev. 2224]. Reviewer questions the success of the attempt. In fact, the problem as formulated is to solve four equations for only three unknowns.

A. von Baranoff, France

2927. Woronetz, K., Deflection of a velocity field from the Laplace field (in Serbian), *Srpska Akad. Nauk Masinski Inst. Zb. Radova* **60**, 8, 97–107, 1958.

Author considers an incompressible and irrotational velocity field with which he associates the Abilimovitch vector (when this vector vanishes it expresses the Cauchy-Riemann condition). The vector is estimated in the case of an isothermal or adiabatic compressible fluid. In the three-dimensional case the vector is expressed with the aid of quaternions and two potential functions, so that the velocities may be deduced through the functional determinants

$$v_x = \frac{\partial\varphi}{\partial x} = \frac{D(\psi_1, \psi_2)}{D(y, z)}, \ldots.$$

M. Misicu, Roumania

2928. Maczynski, J., Transient response of mine ventilation networks during fan reversal (in English), *Bull. Acad. Polonaise Sci.* **7**, 6, 407–411, 1959.

The one-dimensional equations governing flow of an ideal gas in a duct of varying cross section are developed with fluid volume discharged (Ω) and duct volume as independent variables. Two limiting cases are given which bound the actual transient problem. General solutions for discharge and time as functions of Ω are given in the form of integrals. Author performs the integration for the braking time in a horizontal duct of constant cross section.

W. P. Graebel, USA

2929. Naumann, A., and Prause, J., Flow processes at the inlet pipes at high velocities (in German), Jahrbuch Wissenschaft. Gesellsch. Luftfahrt, 1958, 70–79.

A contraction of a gas jet, depending on the condition of the free stream, occurs at the entrance of a pipe. When increasing the efficient pressure difference, sonic speed is reached in the cross-section area of greatest contraction, particularly in the case of intakes with a sharp edge; the critical section suddenly moves from its downstream position at the end of the pipe to the intake, the latter now controlling the mass flow. Therefore the mentioned critical condition of flow involves a critical Mach number of the intake. Above this critical Mach number the contracted area acts like a Laval nozzle with a fluid wall.

In the first part of the present paper the properties of the flow are considered for one-dimensional flow.

In the second part the flow pattern is described with reference to schlieren photographs; the authors try to give a more detailed explanation of the condition of flow in the region of contraction. At the convex surface of discontinuity the local field of supersonic flow is considered, which, due to the reciprocating effect of modulation and rolling-up of vortices along the surface of discontinuity, causes the formation of shocks.

In the region of the critical Mach number a rapid increase of the contraction ratio is observed, followed by an increase of the mass flow until a normal shock is finally formed at the downstream end of the fluid Laval nozzle.

Finally, the property of a very short tube (a hole in a thick wall) is discussed in brief.

Explanatory schlieren pictures are reproduced.

From authors' summary

2930. Nocilla, S., Existence of points with infinite acceleration, in transonic flow, on the contour of wing profiles of finite curvature (in Italian), *Atti Accad. Naz. Lincei R. C. Sci. Fis. Mat. Nat.* (8) **26**, 2, 197–206, Feb. 1959.

Author makes a very interesting contribution to the solution of the important theoretical problem of existence of shock waves in transonic flow for $M < 1$.

The assumed theoretical condition of shock wave existence is the appearance of an infinite acceleration in one point of the flow on the profile, and not the existence of a singular line in the hodograph plane, as was assumed by previous authors.

The analysis is carried out in general terms using Tricomi's transonic flow equations, and a particular application to an airfoil with constant curvature is worked out.

W. Fiszdon, Poland

2931. Schafer, M., The stability of shockfree transonic gas flows (in German), Jahrbuch Wissenschaft. Gesellsch. Luftfahrt, 1958, 64–69.

The problem for discussion is whether in a plane potential flow

with supersonic velocity a continuous transition to subsonic velocities is possible or whether the transition is only possible by means of a shock wave, i.e. discontinuous. Whereas till now experiments have only shown discontinuous transition, mathematically a class of solutions of the basic gas dynamic equations is known which corresponds to a unilaterally bounded (infinitely extended) flow, where a supersonic region is contained without a shock in a subsonic flow. The shape of the boundary, however, is completely defined. With reference to two basic special cases (potential vortex and flow along a blade) the stability of such a flow is investigated with regard to its return from supersonic to subsonic velocities without the occurrence of a shock if the boundaries in the supersonic region are slightly but arbitrarily modified locally (boundary disturbance). (Disturbances within the subsonic region are physically of less interest.) The natural fundamental condition for vanishing of the disturbance at great distance leads to certain properties necessarily associated with the modified flow at infinity which proves the field character of the problem. The well-known existence theorems (Tricomi, Frankl) (applicable to the hodograph plane) for simple partial differential equations with change from the elliptical to the hyperbolical type cannot be used in the present case.

The calculations of these nonlinear problems are based on the "unitary method of characteristics" formerly developed by the author. From author's summary

2932. Ferrari, C., On transonic flow with an attached shock wave ($M_\infty < 1$): Case of steady motion (in Italian), *Atti Accad. Naz. Lincei R. C. Sci. Fis. Mat. Nat.* (8), **26**, 2, 114-122, Feb. 1959.

An analysis is presented of the details of the flow in the immediate vicinity of the point of intersection of a shock wave and the surface of a smoothly curved airfoil. It is assumed that the expression for the velocity potential immediately upstream of the shock wave can be approximated by the first few terms of a double power series. The shape of the shock wave and the development of the flow immediately downstream of the shock wave are determined by application of the shock relations and a method of local linearization similar to that employed by the reviewer in other problems of transonic flow theory.

It is found that the curvature of the shock wave has a logarithmic infinity at the point of intersection with the airfoil. The velocity distribution along the airfoil is also determined and it is shown that the flow experiences a rapid acceleration immediately downstream of the shock wave, the magnitude of which depends strongly on the local Mach number, but not on the acceleration, immediately upstream of the shock wave. The magnitude of the acceleration increases rapidly as the Mach number upstream of the shock wave diminishes towards unity, and the results appear to indicate that the flow behind the shock wave may accelerate to supersonic velocities in cases for which sonic velocity is exceeded only slightly in the region upstream of the shock wave. The paper closes with two alternative conjectures regarding the interpretation of the results. J. R. Spreiter, USA

2933. Iur'ev, I. M., On plane nozzle design, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **22**, 6, 1202-1204, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Author has given a new particular solution for the approximate system of equations of motion of a gas, which is close to the Chaplygin system of equations over a large transonic range of variation of velocity. This solution can be used for nozzle design. From author's summary by P. Franke, Germany

2934. Wachtell, G. P., and Carfagno, S. P., Supersonic flow in a tube with longitudinal slots, *Physics of Fluids* **2**, 5, 521-526, Sept./Oct. 1959.

A differential equation is derived for the pressure along the axis of a longitudinally slotted tube through which there is supersonic gas flow, for the general case in which both the tube cross section and the slot width vary with axial position. An approximate method of solution for the special case, in which the tube cross section and slot width are constant, is then found in closed form and confirmed experimentally to within a constant factor. This factor is attributed to the formation of a boundary layer along the slot walls.

From authors' summary by A. Kitter, USA

2935. Vorob'ev, O. S., An approximate analytical expression for two-dimensional supersonic gas flows, *Soviet Phys.—Doklady* **3**, 5, 923-927, May 1959. (Translation of *Doklady Akad. Nauk SSSR (N. S.)* **122**, 5, 778-781, Oct. 1958 by Amer. Inst. Phys., Inc., New York, N. Y.)

Potential and stream functions φ and ψ satisfy $\partial^2\varphi/\partial\lambda\partial\mu = F(t)(\partial\varphi/\partial\lambda + \partial\varphi/\partial\mu)$ and $\partial^2\psi/\partial\lambda\partial\mu = -F(t)(\partial\psi/\partial\lambda + \partial\psi/\partial\mu)$, where $4F = (\gamma + 1)M^4(M^2 - 1)^{-1.5}$. Since characteristic variables $2\lambda = t - \theta$ and $2\mu = t + \theta$ are constant on epicycloids in hodograph plane, $t = \lambda + \mu$ is known function of M. Author uses approximation $F = k/(c - t)$ with constants k and c. For $\gamma = 1.4$, $k = 3$ and $c = 2.8$ yield fantastically good fit of F for $M \geq 3$. For this new F, familiar solution of Euler-Poisson-Darboux equation yields φ and ψ in terms of two arbitrary functions $f_1(\lambda)$ and $f_2(\mu)$. Author determines forms of f_1 and f_2 required for solutions of various standard boundary problems of plane flow theory.

Paper is potentially a very significant contribution.

J. H. Giese, USA

2936. Shmyglevskii, Iu. D., On some properties of axially symmetric supersonic gas flows, *Soviet Phys.—Doklady* **3**, 5, 928-930, May 1959. (Translation of *Doklady Akad. Nauk SSSR (N. S.)* **122**, 5, 782-784, Sept. 1958 by Amer. Inst. Phys., New York, N. Y.)

Consider a characteristic extending downstream from a point A on a body to a point C on a shock. Let s be arc length on AC measured from A. Let α be Mach angle and θ flow inclination relative to the axis of symmetry. Now change shape of the part of the boundary downstream from A. Author proves increase of radius of curvature at A (1) decreases values of $d\theta/ds$ and $d\alpha/ds$ on AC, and (2) increases radius of curvature of shock at C.

J. H. Giese, USA

2937. Jorgensen, L. H., and Perkins, E. W., Investigation of some wake vortex characteristics of an inclined ogive-cylinder body at Mach number 2, NACA Rep. 1371, 19 pp., 1958.

2938. Perkins, E. W., Jorgensen, L. H., and Sommer, S. C., Investigation of the drag of various axially symmetric nose shapes of fineness ratio 3 for Mach numbers from 1.24 to 7.4, NACA Rep. 1386, 17 pp., 1958.

Book—2939. Truitt, R. W., Hypersonic aerodynamics, New York, The Ronald Press Co., 1959, xii + 462 pp. $10.

Interest in hypersonic flow has increased markedly in the last few years in connection with missiles and astronautics. This book is a text for students and for those working in the field without formal training. It assumes a first course in aerodynamics, background in physics and mathematics through differential equations and vector analysis. The book is comparable to Pai's "Introduction to the theory of compressible flow"; but is on a lower level than the monograph "Hypersonic flow theory" by Hayes and Probstein.

The emphasis is on inviscid flow. Reviewer believes it is a very well-organized account which should enable the reader to handle a large variety of problems on the engineering level. A

conscientious attempt is made to indicate the range of applicability of the various methods. However, the treatment of the boundary layer is very limited and reviewer has some reservations about the last chapter on real gas effects. For example, the short-wave calculations (Figs. 10-1 to 10-3) do not take dissociation into account. In the discussion of dissociation behind a shock which is based on the paper by Wood [AMR **12** (1959), Rev. 2477] no indication is given of the large uncertainty in the reaction rate. Reviewer cannot evaluate the material on magnetoaerodynamics critically but it appears well written and stresses possible applications.

Reviewer objects to uses of hypersonic boundary layer instead of hypersonic shock layer but must admit that there are precedents in the literature. Also the author has sent reviewer a list of errata containing approximately twenty items.

The problems (and solutions) at the end of the text should be useful to instructors. W. Squire, USA

2940. Cheng, H. K., Similitude of hypersonic real-gas flows over slender bodies with blunted noses, *J. Aero/Space Sci.* **26**, 9, 575-585, Sept. 1959.

On the basis of the hypersonic small-perturbation theory, the laws of similitude for hypersonic inviscid flow fields over thin or slender bodies are examined, and the restrictions to ideal gases with constant specific heats and to bodies with pointed noses are removed. Only steady plane or axisymmetric flows are considered.

Inspection of the governing system of equations shows that a similitude law exists for flow fields, under local thermal equilibrium, having the same free-stream atmosphere. For flows of ideal gas with constant specific heats, the requirement of the same free-stream atmosphere—i.e., the same composition, pressure, and density—can be replaced by the requirement of the same ratio of specific heats γ.

For flows over blunted wedges or cones, special laws of similitude can be obtained.

Application of the similarity rules is examined for the case of hypersonic flows of an ideal gas with $\gamma = 1.40$ over flat plates with blunt leading edges, and for the case of equilibrium air flows over wedges. The possibility of simulating nonequilibrium flows over slender or thin bodies is also pointed out.

From author's summary by L. N. Tao, USA

2941. Muggia, A., Aerodynamic field near the stagnation point of a blunt symmetrical airfoil in hypersonic flow with γ near unity (in English), AFOSR TN 59-339 (Lab. Meccan. Appl. Politecn. Torino TN 13; ASTIA AD 213 660), 15 pp., Feb. 1959.

A blunt symmetrical airfoil in a steady axial hypersonic flow is considered in the limiting case of free-stream Mach number infinite and ratio of specific heats near unity. Viscosity, dissociation and ionization are neglected. A method is obtained to determine the aerodynamic field near the stagnation point, starting from Whitham's theory and taking into account the fluid compressibility behind the shock and the curvature change along the airfoil. Very simple approximate formulas are derived for velocity and pressure distribution along the airfoil. Calculation results are compared with Newtonian approximation as an example, showing substantially steeper static pressure drop on airfoil surface. P. Schwaar, USA

2942. Monaghan, R. J., Problems of hypersonic aerodynamics—a survey, *J. Roy. Aero. Soc.* **63**, 585, 489-492, Sept. 1959.

2943. Cox, R. N., General characteristics of hypersonic flow fields, *J. Roy. Aero. Soc.* **63**, 585, 503-508, Sept. 1959.

2944. Mangler, K. W., Some special aspects of hypersonic flow fields, *J. Roy. Aero. Soc.* **63**, 585, 508-512, Sept. 1959.

2945. Crabtree, L. F., Hypersonic boundary layers with special reference to heat transfer, *J. Roy. Aero. Soc.* **63**, 585, 513-516, Sept. 1959.

2946. Ryzhov, O. S., and Khristianovich, S. A., On nonlinear reflection of weak shock waves, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **22**, 5, 826-843, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

This mathematical study is concerned with reflections that occur e.g. as an expanding hemispherical shock wave interacts with the rough surface of its bounding equatorial plane. The particular reflection investigated is that between a straight ramp on the surface facing the oncoming weak shock, for small angles between the normal to the wall and the wave front. Although the shock pressure is small the variation of propagation velocities may not be disregarded, and consequently the analysis cannot be based upon the acoustic linearizations. It is found that the pressure gradients are significant, which in this case are large because of the small spacial extent of the pressure regions not only in radial but also in azimuthal direction. The nonlinear equations for these "short waves" are established and exact particular solutions are derived by use of the fact that variations take place only in a small region adjacent to the wave front. These solutions are then used for the approximate treatment of the problem of nonlinear reflection from a perfectly rough wall.

Results are given for various ramp angles of incidence and it is shown that the extent of the regions of increased pressures is restricted so as to require instruments of high resolution for their measurement. J. R. Weske, USA

2947. Lun'kin, Yu. P., The parameters of a gas beyond a shock wave, *Soviet Phys.—Tech. Phys.* **4**, 2, 155-161, Aug. 1959. (Translation of *Zh. Tekh. Fiz. USSR* **29**, 2, 180-189, Feb. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

It is shown that when effects of the variable specific heat are taken into account, the parameters of a gas beyond a shock wave are determined by the effective γ^1, and not by $\gamma = c_p/c_v$. For gases with low dissociation energies there can be intersection of the corresponding frozen and equilibrium shock adiabatics and shock polars.

From author's summary by K. Schneider, USA

2948. Meyer, R. E., and Ho, D. V., Non-uniform shock propagation in a stratified atmosphere, Brown Univ., Div. Appl. Math. TR 20, (Contract Nonr-562(07)), 32 pp., July 1959.

An analysis is made of the motion of a very strong plane shock wave in a gas which has appreciable density gradients in the direction of motion; the agency by which these gradients are produced is not taken into account. The equations of motion of the gas behind the shock are attacked by an expansion in terms of the entropy differences behind the shock. The solution is compared with the simple result obtained, for strong shocks, by Whitham's hypothesis [AMR **12** (1959), Rev. 3483] and one of the objects of present paper is to obtain information on the range of validity of this hypothesis. Whitham's result is obtained as the zero-order term of the expansion which neglects entropy differences. The higher-order terms in the expansion are stated to be valid for a large range of density gradients and provide corrections to Whitham's solution. Heavy gases (for which $\gamma \to 1$) are also considered and, since the entropy changes are very small in such gases, Whitham's approach again gives a good first approximation. G. A. Bird, Australia

2949. Kochina, N. N., and Mel'nikova, N. S., On the nonstationary motion of gas displaced by a piston, taking counterpressure into account, *Soviet Phys.—Doklady* **3**, 5, 918-922, May 1959. (Translation of *Doklady Akad. Nauk SSSR (N. S.)* **122**, 2, 192-195, Sept. 1958 by Amer. Inst. Phys., Inc., New York, N. Y.)

Into initially stagnant gas let a "piston" $r = r_s(t)$ advance with velocity $v_s(t) = ct^m + Bt^{-m}$, where B, c, and m are constants. Let $r_s(t)$ be radius of corresponding plane, cylindrical, or spherical shock. Let v_2, p_2, and ρ_2 be velocity, pressure, and density immediately behind the shock. Let $\lambda = r/r_2$, $q = (\gamma p_1/\rho_1)/(dr_2/dt)^2$, $f(\lambda, q) = v/v_2$, $P(\lambda, q) = p/p_2$, $R(\lambda, q) = \rho/\rho_2$, where subscripts 1 refer to undisturbed gas. Write $f = f_0(\lambda) + f_1(\lambda)q \ldots$, express P and R similarly, and set enthalpy $s = (\ln A_0 q) + Aq \ldots$, where A_0 and A are constants. Authors choose f_0, P_0, and R_0 known for "self-reproducing" flow without counterpressure. Substitution in equations of one-dimensional flow yields system of linear ordinary differential equations for f_1, P_1, R_1. Authors have solved this numerically for $m = \pm 0.4$ and ± 0.5 for spherically symmetrical flow including counterpressure. J. H. Giese, USA

Boundary Layer

(See also Revs. 2901, 2910, 3024, 3044, 3045, 3047, 3106, 3185)

Book—2950. Gortler, H., editor, Symposium on boundary layer research (International Union of Theoretical and Applied Mechanics, Freiburg, Germany, Aug. 1957); Berlin, Springer-Verlag, 1958, xii + 411 pp. DM 67.50: (Revs. 2951–2981).

2951. Townsend, A. A., The turbulent boundary layer (in English), 1-15.

Author's name is associated with the investigation of large-scale eddy motions intermediate between the mean flow and the turbulent fluctuations of finer structure. First part of the present contribution examines new measurements of the two point velocity correlation tensor. It is inferred from this and other visual evidence that in the outer layer the large eddy motion is comparable to jets emerging from inside (a previous picture of simple roller eddies appears now inadequate). Within the inner layer the large eddies may be two-dimensional jets originating close to the wall.

The second part of the paper concerns the boundary-layer development for a flat plate with a lateral free edge. In the turbulent case, edge effects involve the secondary flow arising from the inequalities of the normal Reynolds stresses. At low Reynolds number, turbulence starts at the free edge and may coexist with neighboring laminar flow. A. J. Craya, France

2952. Bjorgum, O., On the possibility of a mathematical theory of shear-flow turbulence (in English), 16-19.

2953. Ackeret, J., Boundary layer in straight and curved diffusers (in German), 22-40.

Diffusers are considered in which the flow is not separated; thus boundary layers exist all along their length. Using the Gruschwitz method and some empirical relations, author shows that the distribution of the boundary-layer displacement thickness δ^* along a two-dimensional diffuser depends very strongly on the value of δ^* at the entrance, and the diffuser efficiency decreases markedly as δ^* at the entrance is increased. Experiments carried out by the author's collaborators in a two-dimensional and circular diffuser substantiate these conclusions. Measurements were made also in curved diffusers (up to 30°) with the interesting result that even in these cases with strong secondary flows the entrance boundary-layer thickness has a strong influence on the diffuser efficiency. J. Laufer, USA

2954. Ludwig, G., and Metzdorf, J., Boundary layer flow in dissociating nitrogen at high Mach numbers (in German), 41-46.

Calculations are made of thermal conductivity and Prandtl number of dissociated nitrogen as functions of temperature. In the temperature range 3000 K to 7000 K the values are shown to depend significantly on whether diffusion of the molecules and atoms is taken into account. The calculated properties are used to compute velocity and temperature distributions in a laminar boundary layer on a flat plate for a wall temperature of 7000 K and outside flow temperature of 1400 K. The velocity at the edge of the layer is shown to be dependent on whether diffusion is taken into account. A. M. Kuethe, USA

2955. Seth, B. R., Synthetic method for boundary layer thickness (in English), 47-58.

Viscous flow past a flat plate, cylinder and sphere are treated by a technique which appears to the reviewer to be analogous to certain methods in elasticity [AMR **9**(1956), Revs. 28, 29]. A form is assumed for the solution and substituted into the full Navier-Stokes equations. Then an attempt is made to make the error terms, which are interpreted as constraining forces, vanish asymptotically. While the analysis is not carried out to concrete numerical results but only to proportionalities, the idea seems promising. A recent note by Boley and Friedman [*J. Aero/Space Sci.* **26**, 7, 453-454, July 1959] seems to do this for the flat plate.

Reviewer, however, doubts the applicability to turbulent flow, briefly discussed at the end of part 2, and notes that when the boundary-layer thickness is correct the drag law is not, though he believes there is a typographical error in the equation for C_D. W. Squire, USA

2956. Stewartson, K., On rotating laminar boundary layers (in English), 59-71.

Extension of work started by Howarth [AMR **5**(1952), Rev. 1156] who dealt with a rotating sphere in a fluid otherwise at rest, and found that sphere acted like a centrifugal fan with an inflow at the poles and an outflow at the equator. Boundary layers start at each pole and converge toward each other at the equator, where they separate. At this point Howarth's solution became inadequate. Paper extends the solution near the equator showing that there must be a very thin layer near the equatorial plane. Ultimately far from the sphere the flow will take the form of Squire's radial jet [AMR **9**(1956), Rev. 4004].

Author also considers a rotating cylindrical half body terminated by a hemisphere. Boundary layer starts at the pole as before. Over the cylinder it approaches the form of Glauert's wall jet [AMR **10**(1957), Rev. 4068] but later the pressure gradient across the boundary layer (hitherto considered to be zero), and later still the curvature terms, must be taken into account. If the cylinder is finite, boundary layers start at each end and meet in the middle as on the rotating sphere.

Paper also considers a sphere at rest in a rotating fluid. Here the boundary layer begins at the equator and spreads around toward the poles. Author believes there to be no breakaway at the poles, which implies that longitudinal and azimuthal velocities reduce smoothly to zero there, as in Bodewadt's problem, *ZAMM* **20**, p. 241, 1940. Paper touches briefly on problem of rotating fluid over a finite disk.

This is an important contribution toward an understanding of boundary-layer problems in a field where there are differences of opinion yet to be resolved. J. C. Cooke, England

2957. Glauert, M. B., On laminar wall jets (in English), 72-78.

This is an extension and generalization of author's earlier paper entitled "The wall jet" which deals with incompressible flow. There it was shown that F, the flux of exterior momentum flux, is a constant. For laminar flow, similarity solution for the velocity profile is obtained which contains F as a parameter. In the present paper, this similarity solution is made more general, employing E. J. Watson's technique. The solution then contains an

additional length parameter associated with the distance which the jet profile takes to assume its final similar shape.

For the compressible case, author reports results obtained by Riley, who deduced a more general equation governing F. The earlier conclusion of constant F becomes a special case when the product of viscosity and density of the fluid is a constant. Applying von Mises transformation to the Prandtl boundary-layer equations, Riley showed that under the condition $\mu\rho$ = constant, the similarity solution is applicable. Brief consideration is also given to perturbations of the basic similarity solution due to small external flow. B. T. Chao, USA

2958. Schubauer, G. B., Mechanism of transition at subsonic speeds (in English), 85-109.

Two previous National Bureau of Standards papers on boundary-layer stability and transition are now regarded as classic in this field. First Schubauer and Skramstad used the vibrating-ribbon technique to experimentally confirm the Tollmien-Schlichting theory. Later Schubauer and Klebanoff investigated the mechanics of transition and were able to confirm the spot theory of Emmons. In the present paper Schubauer reports an investigation by his coworkers Klebanoff and Tidstrom using the vibrating-ribbon technique to determine by what process amplified waves lead to an eventual breakdown of laminar flow and whether the breakdown is an inherently point-like phenomenon.

The investigation showed that waves originating within the scope of small-perturbations developed in an orderly manner until at some point there was the sudden onset of a violent motion, which formed streamwise high energy streaks. It was in these streaks that the breakup occurred. This breakup appears in the outer region of the boundary layer with what may be described as a point origin. With downstream movement the breakup pattern then grows into the well-described turbulent spots or patches. The possibility that intermittent separation plays a role in the breakup process was ruled out because the characteristics of breaking are not seen at the wall, where separation would be found.

Schubauer points out the difference in results between these tests and those of Leite on pipe flow. With forced small disturbances that were intended to be symmetrical Leite found that with gradually increasing amplitude of perturbations the onset of turbulent flow took place by a process of gradual wave distribution, indicating that there was probably no opportunity for the primary wave energy to concentrate and produce the local "explosive" type of breakdown found on a flat plate.

M. H. Bertram, USA

2959. Gortler, H., and Witting, H., Theory of the secondary instability of laminar boundary layers (in German), 110-126.

A theory of secondary instability in essentially two-dimensional laminar flows is presented. This secondary instability is exhibited in the formation of vortices whose axes follow the streamlines of the primarily disturbed flow, and their formation depends on the existence of curvature of the streamlines which may be due to such agents as waviness of a wall or Tollmien-Schlichting waves of primary instability. A theory is explained which relates the occurrence of this secondary instability to the amplitude of sinusoidal waves of primary instability. For a flat-plate boundary layer it was found that secondary instability may occur when waves of primary instability have amplitudes as low as 10^{-4} times the displacement thickness of the layer.

J. E. Plapp, USA

2960. Zaat, J. A., Numerical results in the theory of boundary layer stability (in German), 127-139.

A numerical solution is presented of the problem of boundary layer stability, using the method of Prof. Timman published in his paper "A one-parameter method for the calculation of laminar boundary layers," N. L. L. Rep. F. 35 (1949) [AMR 4(1951), Rev. 356]. Included are several notes concerning the numerical integration of the basic differential equation by means of the Adam's method. The results of numerical calculations are plotted in diagrams expressing the indifference curves for the disturbance wavelengths, disturbance frequency and disturbance wave propagation velocity as functions of the Re number. Theoretical results are in good agreement with the results of Schubauer and Skramstad's measurements.

J. Polasek, Czechoslovakia

2961. Lin, C. C., On the instability of laminar flow and its transition to turbulence (in English), 144–160, (includes appendix by L. N. Howard).

Recent developments in the theory of the stability of laminar flow are surveyed. The two principal processes associated with finite amplitudes, distortion of the mean flow and generation of harmonics, are considered.

The work of Stuart indicates that consideration of the first process alone accounts for the transition regime in flow between rotating cylinders. Here it is shown that for parallel flows there is a critical layer in which all the harmonics simultaneously become important before the amplitude is large enough to distort the mean flow. A treatment of this critical layer requires an asymptotic solution of the Orr-Sommerfeld equation uniformly valid to third-order terms. A method of obtaining such a solution is indicated.

An appendix by L. N. Howard treats the problem of the stability of a jet briefly. In this connection the recent work of McKoen and of Curle, AMR 10(1957), Revs. 3359 and 3360, should be consulted.

W. Squire, USA

2962. Eichelbrenner, E. A., and Michel, R., Comparison of theoretical methods for estimating laminar turbulent transition in three-dimensional flow with experiments in ONERA Cannes wind tunnel, (in German) 161-172.

A semi-empirical criterion of R. Michel [AMR 6(1953), Rev. 3186] for the determination of transition can be generalized on axisymmetric bodies by using a special Mangler transformation. For zero or small angles of attack or small deviations from rotational symmetry the generalized criterion shows satisfactory agreement with experimental results. For axisymmetric bodies with larger angles of attack the streamlines on the side walls are spacially curved to a considerable extent. This causes a pressure gradient transverse to the streamlines and consequently within the boundary-layer velocity components transverse to the streamlines of the outer flow. According to Owen and Randall [R. A. E. Farnborough—Tech. Mem. Aero 277, 1952] this cross flow has a destabilizing effect on the laminar boundary layer. With $|w_{max}|$ maximum value of the cross-flow velocity component, δ boundary-layer thickness and ν kinematic viscosity, transition occurs independently of the longitudinal instability, if the critical Reynolds number $R_w = |w_{max}|\,\delta/\nu$ reaches 125. On axisymmetric bodies with angle of attack, transition occurs on those lines where either the Michel-Mangler criterion or the Owen-Randall criterion is reached. On the upper and lower wall the first criterion is always predominant; on the side walls the latter, if the angles of attack are large enough. A. Betz, Germany

2963. Bergh, H., A method for visualizing periodic boundary layer phenomena (in English), 173–179.

Preliminary side-view observations of the boundary-layer instability and transition on NACA 0012 airfoil excited by a loudspeaker located at the top of the wind-tunnel test section. The flow is visualized by kerosene smoke with the aid of stroboscopic illumination. The boundary layer is seen to form periodic vortices,

in approximate agreement with the stability theory, and breaks up into turbulence accompanied by the formation of horse-shoe vortices. No references are given. F. R. Hama, USA

2964. Ostrach, S., Internal viscous flows with body forces (in English), 185-208.

"A series of problems dealing with the flow of confined viscous fluids subject to body forces are discussed and it is shown that numerous factors can appreciably affect the flow and heat transfer. In particular, the effects of the confining walls, heating the fluid from below, frictional heating, and rotating the fluid container are studied. The configurations considered simulate heat sinks in turbine blades, nuclear reactors, and high-speed re-entry vehicles."

Most of the individual problems have been reported in greater detail in AMR **10**(1957), Rev. 4190; **11**(1958), Revs. 1004, 2332, and 5157. W. Squire, USA

2965. Schuh, H., Determination of the temperature distribution in thin plates with attached supersonic boundary layer (in German), 209-223.

Author uses difference method solution of a time-dependent heat-conduction problem in a solid plate with convective and radiative boundary conditions due to adjacent supersonic boundary layer. By assuming the plate to be thin and having uniform cross-sectional temperature, author reduces the problem to one-dimensional treatment with low Mach number supersonic flow. It would appear that the purpose of this paper is to show how the difference equations method compares with the analytical solution for this problem obtained by other investigators. Graphs plotted in this paper indicate satisfactory agreement.

This reviewer feels that the basic assumptions made in this paper about geometry of the plate and the nature of heat-transfer coefficient simplify the nature of the transient heat-conduction problem to such an extent that analytical solution would appear much faster and simpler. On the other hand, the difference method adopted by author from the well-known literature on this subject could be used much more profitably for complex geometrical shapes and more involved boundary layers. Method described by author necessitates the knowledge of analytical expressions for boundary heat conductance which is only known for simple shapes. The difference method, to render it of any value for the problem of transient conductance, should be capable of dealing with the boundary conductance in a more general, nonanalytical fashion.

B. Zarwyn, USA

2966. Popper, B., and Reiner, M., Cross-stress in air, demonstrated by means of a centripetal vacuum pump (in English), 224-226.

Authors describe centripetal air pressure pump which was built in order to prove the theory of "cross-stresses" in laminar flow of air, i.e. normal stresses in the direction of the velocity of flow and and of the velocity gradient.

Z. Bychawski, Holland

2967- Schaaf, S. A., and Talbot, L., Boundary layers in a rarefied gas (in English), 227-228.

2968. Lunc, M., and Lubonski, J., Theoretical analysis of the aerodynamics field near an infinite plate on the basis of the kinetic theory (in French), 229-235.

The stationary motion of a gas in the vicinity of an infinite wall is investigated by using a "demographic" method for determining the distribution function of the molecular velocities. The principal idea of this method, which evades the complicated Boltzmann equation, consists in classifying the molecules according to the station of their last collision. All collisions are supposed to be perfectly diffuse and the mean free path is assumed to be constant and independent of the velocities of the colliding molecules, a simplification which was considered in the discussion of G. Temple as too drastic for accurate calculation. After determining the distribution function, relations for density, temperature and heat transfer are deduced.

W. Wuest, Germany

2969. Gadd, G. E., Interactions between shock waves and boundary layers (in English), 239-255.

Paper reviews present knowledge of subject matter and discusses a number of as yet not fully explained discrepancies between experimental results obtained under apparently similar conditions. Several proposed experiments at the N. P. L. are outlined.

Reviewer found paper an excellent review of the physics of shock-wave boundary-layer interactions.

N. H. Johannesen, England

2970. Ferrari, C., Influence of the boundary layer on airfoil pressure at supersonic speeds (in English), 256-282.

The problem is not the usual determination of the moderate alteration in pressures associated with an apparent thickening of an airfoil section when enveloped by an unseparated boundary layer, but rather an examination is made of the regenerative influence exerted far upstream, at supersonic speeds, between the boundary layer formed over the aft end of an airfoil and the shock-wave interference system which is set up.

What is sought is not merely a means of determining the pressure adjustments which are produced over the forward part of the airfoil as a result of the apparent thickening that is associated with the progressive growth of the boundary layer, but knowledge is also required as to what size of pressure increment, Δp, will produce a detachment, such as is known from optical studies to take place when the flow is laminar. After obtaining the upstream flow characteristics, it is then possible to determine the detailed nature of the detached jet, and the position of the separation point then becomes resolved by examining the conditions which must be fulfilled downstream.

From author's summary by C. B. Ludwig, USA

2971. Mirels, H., The wall boundary layer behind a moving shock wave (in English), 283-293.

The boundary layer behind a shock is important for treating attenuation in shock tubes. Fay [*Physics of Fluids* **2**, 3, 283-9, May/June 1959] has also used boundary-layer results to explain velocity deficit of detonation waves in tubes of finite diameter.

In this paper the analysis of the laminar boundary layer takes the temperature dependence of the gas properties into account, which is important for strong shocks. The turbulent boundary layer is treated by assuming a Prandtl number unity and making an assumption relating the velocity distribution to the usual wall boundary layer. Reviewer notes it can be shown from author's previous work that this assumption is not exact for laminar flow but cannot estimate error for turbulent flow.

The boundary-layer results are used to compute the wall temperature history in shock tube and results are in good agreement with experiment. Paper concludes with a brief discussion of transition. W. Squire, USA

2972. Moore, F. K., On the separation of the unsteady laminar boundary layer (in English), 296-311.

An analysis shows that the general motion near a separation point in an unsteady incompressible laminar boundary layer which is nearly quasi-steady may be resolved into two problems, one of

which is that of finding unsteady corrections to the boundary-layer solution when the quasi-steady separation point is stationary. In such a case, the familar definition of separation as the place where wall shear vanishes is correct. The second problem is in essence that of a steady boundary layer separating over a moving wall. Here the chief problem is to establish a proper definition of separation. R. C. Binder, USA

2973. Person, L. N., Solution of nonsteady boundary layer flows by integral transforms (in German), 312-318.

The advantage of the application of integral transforms to the solution of unsteady boundary-layer problems is shown in two examples. The first problem is concerned with the calculation of the boundary-layer profile for an infinite plane which, until $t = 0$, is at rest and then starts to move with a velocity $U_0 + u_0 \sin \omega t$ in its own plane. This problem is identical to a problem in the theory of heat conduction. The second problem deals with a half-plane which, at $t = 0$, starts to move with a velocity $W_0 + w_0 \sin \omega t$ in the direction of its normal. It is solved by Laplace transformation to the time followed by Fourier transformation to the coordinate in the direction perpendicular to the edge of the plane but in the plane. A. I. van de Vooren, Holland

2974. Wuest, W., Periodic boundary layer suction (in German), 319-329.

A theoretical investigation is presented of the flow over an infinite plate with a periodic distribution of suction intensity perpendicular, parallel, and at an angle to the undisturbed flow direction. The decay of velocity and pressure disturbance, due to the above suction distribution, far from the plate is calculated for the case of an inviscid fluid. An approximate linearized solution is given for the viscous boundary-layer flow. The paper presents an original theoretical solution which may find practical applications in boundary-layer control problems.

W. Fiszdon, Poland

2975. Nikolskij, A. A., Some problems of flow separation in ideal fluids and their significance from the point of view of boundary layer theory (in German), 330-334.

At the leading edge of slender, small-aspect-ratio wings, strong spiral vortex systems and discrete vortices are developed, which have considerable influence on the aerodynamic forces. Author applies old ideas of Prandtl about the generation of vortices in ideal fluids to that problem. For flat wedges starting from rest in an ideal fluid, solutions for similar motion are derived. In the case of a two-dimensional flat plate numerical solutions can be given for the point of separation.

Similar equations hold if viscosity terms are included, but no general solution can be given for the interaction of boundary layer and vortex system. H. Merbt, Germany

2976. Rachmatulin, H. A., Boundary layer theory for homogeneous and two component fluids with two velocities (in German), 335-342.

For a mixture of two liquids or two gases it is assumed that each component satisfies the basic equations of a continuum. For such a fluid consisting of two components the Navier-Stokes equations and hence the boundary-layer equations for the incompressible case are given. For the two-dimensional flow two boundary-layer equations coupled together and two continuity equations are obtained, e.g. four equations for the unknowns u_1, u_2, v_1, v_2 of the two components with the densities ρ_1 and ρ_2 respectively. Generally the boundary-layer thickness of each component will differ from the other. It can be shown that in the case of equal pressure (flat plate) the two boundary-layer thicknesses tend very quickly toward an asymptotic value, namely the boundary-layer thickness of the fluid of the density $\rho = \rho_1 + \rho_2$.

The flow of a two-component fluid in divergent channel with constant pressure gradient is fully treated as an example. The final numerical results, however, in the form of diagrams or tables, are lacking. K. W. Gersten, Germany

2977. Timman, R., Problems in the theory of the three dimensional boundary layer (in German), 348-356.

In this paper the mathematical and physical difficulties of the three-dimensional incompressible laminar boundary-layer problem are discussed. The solution of the problem with the help of two momentum equations in streamline coordinates is based on earlier papers by the author and J. A. Zaat and E. van Spiegel [see AMR **4**(1951), Rev. 3009; **11**(1958), Rev. 561; **10**(1957), Rev. 232; and "Eine Rechenmethode für dreidimensionale laminare Grenzschichten," 50 Jahre Grenzschichtforschung 1955, Braunschweig, Vieweg; and two reports of the National Luchtvaart Lab. Amsterdam.] This résumé is rather brief in details and it is necessary to consult the previous papers for some notations.

Irmgard Flugge-Lotz, USA

2978. Oswatitsch, K., Criteria for boundary layer separation (in German), 357-367.

Analysis of flow very close to a wall in general case, with pressure and wall shear gradients and compressibility considered, yields relationships describing streamline pattern. Navier-Stokes and continuity equations are applied with the boundary conditions at the wall. Result is set of equations giving velocity components in terms of pressure, two components of wall shear stress and their gradients along co-ordinate axes in the wall. For two-dimensional flow a unique result is obtained. The wall streamline leaves, at the separation line, at an angle which is greater the faster the shear stress decreases and the slower the pressure rises. A three-dimensional flow is considered with symmetry about a plane containing the co-ordinate perpendicular to the wall and one of those along the wall. Two types of separation can occur, depending on the pressure and stress gradients. Separation occurs at a point in the plane of symmetry. For a convergent point the flow is toward this point and for a divergent point is away from it, in the direction perpendicular to the plane.

There is one condition under which separation does not occur but is replaced by another phenomenon defined by "flow division" (Reviewer's terminology). The wall streamline upon passing through the separation point divides and continues in the plane of wall, i.e. it does not leave the wall. Beyond the separation point is a region of back flow occupying all of the space. In the general three-dimensional case there is one additional complication of the symmetrical case. The flow may rotate about the separation point forming a vortex separation.

Reviewer finds paper clear and concise. There is, unfortunately, no experimental proof of these patterns which have fundamental importance. W. D. Baines, Canada

2979. Walz, A., New application of the von Karman and Pohlhausen boundary layer integrals (in German), 368-376.

Author discusses the convergence of the general system of boundary-layer equations based on boundary-layer integrals as first defined by von Karman and Polhlausen. A method is proposed for evaluating the error in the solution obtained by using only the first two equations of the general system.

Using the above-mentioned boundary layer integral, a method is proposed for determining the velocity profile in the boundary layer. For determining the velocity at m points within the boundary layer, the method requires the simultaneous solution of $m + 1$ ordinary differential equations of the first order.

Author then shows that the general principal of boundary-layer integrals when applied to the Navier-Stokes equations results in a system of equations different from the system mentioned above in only one term. This term is then discussed and interpreted.

R. W. Detra, USA

2980. Tani, I., Experimental investigation of flow separation over a step (in English), 377-386.

Low-speed pressure and velocity measurements (including velocity fluctuations) in the separated flow over backward-facing steps are described. Base pressure was found to be essentially independent of step height, a result which is consistent with the fact that the (turbulent) shear stress in the mixing region was roughly independent of step height. The shear stress was found to increase with distance downstream from the step.

J. V. Becker, USA

2981. Wehrmann, O., and Wille, R., The phenomena of the laminar turbulent transition in free jets at low Reynolds numbers (in German), 387-404.

When a jet emerges from a nozzle, first a laminar transition region is formed between the jet and the surrounding resting fluid, which soon breaks up into separate ring vortices. These vortices grow, sometimes two vortices fuse and finally decay to turbulent disturbances. With a hot-wire technique developed especially for this purpose, the velocity distribution within the vortices was measured and their development studied. The frequency f of the vortices was found for different diameters D of the nozzle exit to be proportional to $D^{-1/2}$ and for different exit velocities U proportional to $U^{3/2}$. Obviously it depends on the boundary-layer thickness δ^* at the nozzle wall and may be represented by $f = kU/\delta^*$. The Reynolds number range of the experiments was 2500 $< \frac{UD}{\nu} <$ 40,000.

A. Betz, Germany

End of symposium

2982. Gortler, H., On an analogy between instabilities of laminar boundary-layer flows over concave walls and heated walls (in German), *Ing.-Arch.* **28,** 71-78, March 1959.

Author points out the longitudinal vortices observed over heated walls, for which no satisfactory analysis has been made, as the thermo-convective analog to the instability phenomenon occurring in the boundary layer over concave walls, now generally known as Gortler instability. Linearized theory of instability is developed for a two-dimensional boundary-layer flow over a slightly curved wall having uniform temperature slightly different from that outside the boundary layer. Variation in density and viscosity being neglected, the thermal effect manifests itself only in the bouyant force due to temperature difference. The result indicates that the heating of wall has an unstabilizing effect, similar to the concavity of wall, while the cooling has a stabilizing effect, similar to the convexity of wall. Full account of analysis will be published elsewhere.

I. Tani, USA

2983. Yakovlevskii, O. V., On the thickness of the turbulent mixing zone at the boundary of two gas flows with different speed and density (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 10, 153-155, Oct. 1958.

Some considerations are presented on the variation of the mixing length and of the thickness of the turbulent mixing zone between two flows with different speeds. By using Prandtl's hypothesis on the variation of the mixing length in case of free-turbulence, author analyzes the effects of the density of the two flows on the mixing zone thickness. He obtains an analytical formula based on the assumption that the mean velocity in the mixing zone can be deduced through the ratio of the sum of the products of density and speed for the two gas flows to the sum of the two densities. The results are in fairly good agreement with experimental data if the ratio of the flow velocities does not exceed the value 0.4. Formulas are also extended to the compressible case.

V. N. Constantinescu, Roumania

2984. Kao, S.-K., Turbulent transfer in the boundary layer of a stratified fluid *J. Meteorol.* **16,** 5, 497-503, Oct. 1959.

Relying principally on dimensional considerations, author derives relationships between the horizontal wind speed variation with height (wind profile) and the eddy flux of heat. He also treats temperature profiles which have a shape similar to the wind profiles. He evidently has misinterpreted some prior work (e.g. Businger, J. A., 1954, Meded. Verh. k. Ned. Meteor. Inst., no. 61 78 pp.) and his results differ only in minor respects from those of Businger and of Monin and Obukhov [Monin, A. S. and A. M. Obukhov, 1954, Works of Geophys. Inst., no. 24 (151), 163-186]. Author shows the results in the latter work to be a first approximation to his own. Upward heat flux is shown to increase eddy stress beyond that for adiabatic (zero heat flux) conditions. Downward heat flux has opposite effect. No measurements are given to compare author's results with previous work.

F. I. Badgley, USA

2985. Pechau, W., Approximate procedure for the calculation of the plane axisymmetric turbulent boundary layer with arbitrary suction or blowing (in German), Jahrbuch Wissenschaft. Gesellsch. Luftfahrt, 1958, 82-91.

A method for calculating the characteristic values of the turbulent boundary layer is given. The method is based on an approximate solution of the momentum and energy equations of the boundary layer. The method is applicable for arbitrary continuous distributions of the potential velocity as well as for the velocities of suction or blowing along the contour.

The necessary assumptions for the shearing stress at the wall and the turbulent dissipation are taken from the theory of turbulent boundary layer without suction. The calculation not only renders the momentum thickness but also the usual parameters H and $\overline{H}$, the changes of which allow a statement regarding the position of the point of separation.

In the special case of the flat plate with homogeneous suction the well-known solution by H. Schlichting is obtained. Further solutions can be given implicitly for flows with similar profiles of the boundary layer (solution of similarity).

Comparisons with American measurements show quite a good conformity to theory, particularly in the case of suction.

From author's summary

2986. Sparrow, E. M., and Gregg, J. L., The effect of a nonisothermal free stream on boundary-layer heat transfer, *ASME Trans.* **81**E (*J. Appl. Mech.*), 2, 161-165, June 1959.

The temperature of the approaching fluid is assumed to vary linearly with distance from the wall. This condition is also retained as boundary condition at the outer edge of the boundary layer, with due regard being taken to the displacement effect of the boundary layer on the streamlines. First, similar solutions are obtained in incompressible two-dimensional flow with zero pressure gradient. The influence on the heat-transfer coefficient of a nonuniformity in the temperature of the free stream is larger the smaller the Prandtl number. As a simple illustration, a flat plate was considered placed in air ($Pr = 0.7$) with a Reynolds number of 10^5 at a distance of 1 ft from the leading edge. For a temperature difference of 100 F between the surface of the plate and the oncoming air on the streamline ahead of the plate, temperature gradients up to 77 F per inch are of negligible influence. Extensions are given to cases with viscous dissipation and to vari-

able fluid properties. These are however assumed to depend in a particular way on the temperature. This assumption appears a reasonable approximation for gases.

H. Schuh, Sweden

2987. Eschenroeder, A. Q., The compressible laminar boundary layer with constant injected mass flux at the surface, *J. Aero/Space Sci.* **26,** 11, 762-763 (Readers' Forum), Nov. 1959.

2988. Hayes, W. D., and Probstein, R. F., Viscous hypersonic similitude, Institute of the Aeronautical Sciences 27th Ann. Meet., New York, N. Y., Jan. 26-29, 1959; Rep. 59-63, 43 pp.

An extension of classical hypersonic similitude is developed which takes into account the interaction effect of the displacement thickness of the boundary layer. A basic result of this viscous similitude is that the total drag including frictional drag obeys the classical similarity law for the pressure drag. Additional similarity conditions governing viscous effects must be imposed in this similitude.

Underlying the similitude is a new hypersonic boundary-layer independence principle. According to this principle, the principal part of a hypersonic boundary layer with given pressure and wall temperature distributions and free-stream total enthalpy is independent of the (high) external Mach number distribution outside the boundary layer.

Various features of viscous hypersonic similitudes are discussed. It is found, for example, that it applies to three-dimensional boundary-layer interaction effects on flat bodies provided the concepts of strip theory may be applied and provided the aspect ratio is an invariant.

From authors' summary by H. G. Lew, USA

2989. Williams, J. C., III, The compressible laminar boundary layer with arbitrary pressure gradient and wall temperature distribution, *J. Aero/Space Sci.* **26,** 10, 677-678 (Readers' Forum), Oct. 1959.

2990. Dommett, R. L., The critical height of distributed roughness to cause boundary layer transition, *J. Roy. Aero. Soc.* **63,** 588, p. 723 (Tech. Notes), Dec. 1959.

2991. Coleman, W. S., The characteristics of roughness from insects as observed for two-dimensional, incompressible flow past airfoils, *J. Aero/Space Sci.* **26,** 5, 264-280, 286, May 1959.

Extremely detailed description of painstaking experiments simulating insect contamination of airfoil surface in flight. Large numbers of flies, primarily of the Drosophila species, were discharged into wind tunnel upstream of airfoil. Remains of insects impacted on airfoil were found to accumulate in a pronounced peak near leading edge, causing transition in the manner of three-dimensional artificial roughness. Contamination further downstream was less dense and had little effect. It appears that laminar flow could be maintained if area near leading edge could be kept clean by some artificial means. R. J. Hakkinen, USA

2992. Amick, J. L., A semiempirical relation for laminar separation, *J. Aero/Space Sci.* **26,** 9, 603-604 (Readers' Forum), Sept. 1959.

2993. Kelly, M. W., Anderson, S. B., and Innis, R. C., Blowing-type boundary-layer control as applied to the trailing-edge flaps of a 35° swept-wing airplane, NACA Rep. 1369, 23 pp., 1958.

2994. Klein, M. M., Calculation by the integral method of the effect of fluid injection upon an isothermal boundary layer, *J. Aero/Space Sci.* **26,** 10, 686-687 (Readers' Forum), Oct. 1959.

2995. Squire, W., A note on the Blasius equation with three-point boundary conditions, *J. Aero/Space Sci.* **26,** 10, 678-679 (Readers' Forum), Oct. 1959.

Turbulence

(See also Revs. 2898, 2922, 2951, 2952, 2961, 2980, 2981, 2983, 2984, 2985, 2991, 3018, 3047, 3073, 3077, 3079, 3080, 3083, 3104, 3152)

2996. Reid, W. H., The dynamics of isotropic turbulence in two dimensions, Brown Univ., Div. Appl. Math., TR 23 (Contract Nonr-562(07) (NR-062-179), 24 pp., Apr. 1959.

"The dynamical equations which describe the behavior of isotropic turbulence in two dimensions are derived under the assumption that all fourth-order cumulants of the velocity field vanish [and some properties of the solutions of these equations are presented; the initial growth rates of several quantities are computed numerically]. Due to the absence of vortex line stretching, the transfer mechanism which develops in this case differs markedly from the usual three-dimensional one. For example, an initial energy distribution in the form of a single line spectrum is found to remain unchanged. More generally, however, there is found to be an almost equal transfer of energy from the medium-sized eddies to both smaller and larger eddy sizes. The large magnitude of this 'back-transfer' suggests the need for caution when applying the usual cascade arguments to turbulence in two dimensions. These results would seem to be relevant to the problem of the large-scale motions in atmospheric turbulence which are known to exhibit certain two-dimensional characteristics." (From author's summary; [ ] indicate reviewer's comments).

This work is intended primarily for the turbulence specialist, although of interest to meteorologists. Reviewer feels this work to be related to author's earlier paper [Proudman and Reid, *Phil. Trans. Roy. Soc.* (*A*) **247,** 163-189, 1954; AMR **8**(1955), Rev. 1442] in which same assumption is applied to decay of three-dimensional turbulent field. J. L. Lumley, USA

2997. Reid, W. H., One-dimensional equilibrium spectra in isotropic turbulence, Brown Univ., Div. Appl. Math., TR 27 (Contract Nonr-562(07) (NR-062-179), 28 pp., May 1959.

"The one-dimensional equilibrium spectra in isotropic turbulence are given for the physical transfer theories of Heisenberg, Kovasznay and Obukhoff [those of Heisenberg and Obukhoff by numerical integration, Kovasznay's analytically. Tables of all are given. These spectra are of significance because they make possible comparisons with experimental results which are more sensitive, and which compare quantities in terms of which the theories are formulated]. These results [spectra] are then compared with experimental measurements of the spectrum of $\partial^3 u_1/\partial x_1^3$ fluctuations [this comparison tends to show discrepancies at higher wave numbers]. For two of the theories (Heisenberg's and Kovasznay's) reasonable agreement is obtained for $K\eta < 0.4$ [where K is the wave number and η the Kolmogoroff microscale], but for larger values of $K\eta$ there is considerable divergence between the theoretical and experimental results. The relationship between the equilibrium and similarity spectra are also discussed for these two theories." (From author's summary; [ ] indicates reviewer's comments.)

This work is intended primarily for the turbulence specialist. Reviewer believes that detailed comparison with experiment of predictions of Kovasznay's and Obukhoff's theories has not previously been made; by the comparisons made here the limitations of all three theories are clearly exhibited. Reviewer feels that having these spectra explicitly given will prove useful.

J. L. Lumley, USA

2998. Sim Yun Sev, Distribution of velocities in an expanding plane turbulent flow (in Russian), *Kisul Kvakbak. Tekbn. Nauka* **1**, 6, 55–59; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 586.

An equation is derived for the distribution of velocities in a plane turbulent flow in a diffuser with a sufficiently small angle of expansion. The methods of mixing in the central portion of the diffuser are assumed to be approximately constant. Comparison of the calculation results with the experimental data disclosed a sufficiently close convergence. From author's summary

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2999. Werner, J. E., Shock wave-turbulence interaction, investigations in a shock tube, AFOSR TR 59-46 (Johns Hopkins Univ., Dept. Aero.; ASTIA AD 214-847), 177 pp., May 1959.

Various aspects of the shock-turbulence interaction problem have been investigated analytically and experimentally. These are (1) a cellular vortex field with a discrete front convecting through a shock, (2) a random velocity fluctuation field carrying through a shock by the mean flow. In each case, the pressure fluctuation and the shock displacement were studied. It was found that pressure fluctuation level depends on shock displacement, turbulence scale and turbulence intensity. All these quantities were measured and agreement with theory was obtained.

Y. H. Kuo, China

3000. Frenkiel, F. N., Atmospheric diffusion in air-pollution studies, Proceedings, Seventh Hydraulics Conference, Iowa Institute of Hydraulic Research, June 16–18, 1958; Iowa City, Iowa, State Univ. of Iowa, 1959, 111–131.

The main point made is that if the speed, direction, and turbulence structure of a typical wind are known as functions of time and space, smog distribution can be calculated from a knowledge of the locations and (time-dependent) strengths of smog sources.

C.-S. Yih, England

3001. Semenov, E. S., Apparatus for the measurement of turbulence in a piston motor (in Russian), *Pribory i Tekhn. Eksperimenta* no. 1, 93–101, 1958; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 589.

A description is given of apparatus designed to investigate the turbulence of cyclic flows in conditions of variable temperatures and pressures, such as would be found, for instance, in the cylinder of a piston motor. The apparatus automatically carries out the necessary functional transformations and the statistical analysis of the impulse signals of the electro-thermo-anemometer and gives readings for the mean and pulsating velocities in the point of the cycle being investigated. The apparatus also provides for the frequency spectrum of the turbulent pulsations.

From author's summary

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

Aerodynamics

(See also Revs. 2930, 2932, 2933, 2941, 2970, 2988, 2991, 3059, 3104, 3111, 3120)

3002. Luke, Y. L., and Fettis, H. E., Tables of generalized aerodynamic forces for triangular wings with supersonic leading edges, WADC TR 58-681 (ASTIA AD 211 654), 169 pp., Feb. 1958.

The values of the generalized aerodynamic forces listed in the tables are calculated with the aid of formulas established in a previous paper by Y. L. Luke, P. C. Constant, and B. Rullman [WADC TR 56-525, Oct. 1956]. The oscillating motion of a triangular wing with supersonic leading edges is considered and the generalized aerodynamic forces are estimated by applying the reverse flow principle. It is assumed that modal description of the triangular wings is available in the form of a double polynomial series in x and y, which represent the chordwise and spanwise coordinates respectively. Formulas are given without including the proof, which is contained in the cited reference. Numerical values are listed for three values of the sweep angle of the leading edge, i.e., 30°, 45°, and 60°. For each of these angles several values of the Mach numbers included within 1.2 and 3 are considered.

T. D. Oroveanu, Roumania

3003. Bryson, A. E., Symmetric vortex separation on circular cylinders and cones, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 643–648, Dec. 1959.

When a circular cylinder is suddenly accelerated from rest to a speed V in a fluid (Mach no. $\ll 1$), the initial flow field is closely irrotational, but soon afterwards "the boundary layer separates at the rearward stagnation point and two separation points propagate symmetrically away from this point around the sides of the cylinder. When these boundary-layer separation points reach a certain angular distance from the rearward point, two regions of vorticity break away from the boundary layer and move downstream, beginning the formation of a wake." Paper is concerned with this initial wake development. This problem is also related to symmetric vortex separation observed on the leeward side of slender bodies of revolution at high angle of attack in the subsonic to moderately supersonic range. Cylinder problem is solved by a "lumped-vorticity" approximation, in addition to equations based on the complex velocity potential representing the free-stream flow, a doublet, the two vortexes in the wake, and the reflection of the two vortexes in the cylinder. Equations for the vortex motion are solved numerically. Body vortex position and normal force per unit length are presented for a cylinder and a slender cone at high angle of attack and compared with available experimental evidence.

M. Morduchow, USA

3004. Krasil'shchikova, E. A., Nonsteady motions of a wing of finite span in a compressible medium (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 3, 25–32, Mar. 1958.

A method formerly established for two-dimensional problem is extended to cover the case of finite span. The planform of wing is supposed to be such that tip effects and vortex sheet influences on the wing are excluded.

A. Von Baranoff, France

3005. Vorob'ev, N. F., Nonsteady oscillations of a thin wing in supersonic flow (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 3, 153–156, Mar. 1958.

Author considers two problems: the first one is concerned with effects due to an instantaneous change of law of the superposed motion, the second one includes tip effects and leads, under the assumption of harmonic motion, to a system of integral equations of Volterra type.

A. Von Baranoff, France

3006. Jorgensen, L. H., Elliptic cones alone and with wings at supersonic speeds, NACA Rep. 1376, 24 pp., 1958.

See AMR **11** (1958), Rev. 2230.

3007. Thomas, F., Aerodynamic characteristics of swept and delta wings in ground proximity (in German), Jahrbuch Wissenschaft. Gesellsch. Luftfahrt, 1958, 53–61.

A method based on the extended lifting-line theory is given which allows calculating the lift distribution near the ground for airfoils of arbitrary planform, particularly sweptback and delta wings. The ground effect is taken into account by the reflection method. The velocities induced by the reflected airfoil at the actual airfoil considered are calculated in accordance with a method given by K. Gersten.

The theoretical results are well confirmed by comparative measurements taken from a sweptback wing and a delta wing in

the wind tunnel of the Institut für Strömungsmechanik of the TH Braunschweig. Theory and experiment indicate an increase of the lift curve slope and a decrease of the induced drag near the ground. Apart from these comparative measurements, ground effects on the position of the aerodynamic center, the maximum lift and the flap effectiveness have been investigated.

From author's summary

3008. Wegener, F., Programming of calculation procedures for the lift distribution on wings (in German), Jahrbuch Wissenschaft. Gesellsch. Luftfahrt, 1958, 48–53.

Methods are developed for an arbitrary sweptback wing which allow programming airfoil methods. It appears advantageous to subdivide the problem into three sections. Of these, the first part covers the analytical definition of the coordinates of the quarter-chord points and the trailing edge, the second part deals with the analytical investigation of the values of the influence function, and the third one deals with the computation of lift and pitching-moment distributions by solving a system of linear equations.

From author's summary

3009. Weber, J., An estimate of the suction peak on infinite sheared wings, *J. Roy. Aero. Soc.* **63,** 584, 476–477 (Tech. Notes), Aug. 1959.

3010. Portnoy, H., The drag of ducted bodies with annular or side intakes in supersonic flow, *Aero. Quart.* **10,** 3, 283–295, Aug. 1959.

Slender ducted bodies of arbitrary cross section, possessing an annular, side or "scoop" type of intake at some streamwise section, are studied. Both the forebody and the afterbody (before and behind the intake) may have discontinuities of longitudinal profile slope at certain streamwise stations which should be not too close to each other or to the intake. The external flow is supersonic and it is assumed that the internal flow remains supersonic for at least a small distance after the intake.

On the basis of slender-body theory the wave drag of an isolated forebody or afterbody, neglecting the base drag as well as the drag of the internal flow, has been given earlier [AMR **10** (1957), Rev. 1521]. In the present paper the interference drag, which is the drag of the afterbody in the presence of the forebody minus its drag when isolated, is given.

Results have been applied to bodies with two longitudinal symmetry planes and elliptic cross sections. An example is given of a configuration with an elliptic afterbody, which has a few per cents smaller drag than one with a circular afterbody with the same distribution of cross-sectional area, the forebodies being also identical.

A. I. van de Vooren, Holland

3011. Klinar, W. J., and Grantham, W. D., Investigation of the stability of very flat spins and analysis of effects of applying various moments utilizing the three moment equations of motion, NASA Memo 5-25-59L, 50 pp., June 1959.

Flat spins of airplanes have become more prevalent than in the past, along with the trends toward lengthened fuselage forebodies, increased relative distribution of mass in the fuselage, and low-span wings. Research results, in general, have indicated the important effects of such factors as mass distribution and fuselage-nose cross-sectional shape on the overall stability of a potential spinning motion in determining the nature of spins achieved for current configurations.

Accordingly, an analytical investigation was undertaken to determine how a flat-spin condition, on a specific design, would be influenced by stability characteristics. This problem is analyzed by utilizing only the linearized pitch, roll, and yaw equations of motion. This approach seems reasonable inasmuch as model force-test data show little change in the aerodynamic forces for small side-slip angles and for variations in angle of attack in the flat-spin region. Also, the recovery motion of the airplane appears to be affected primarily by the action of the moments rather than of the forces. The effects of applying various moments in a flat spin have been examined.

L. Goland, USA

3012. Fisher, L. R., Experimental determination of effects of frequency and amplitude on the lateral stability derivatives for a delta, a swept, and an unswept wing oscillating in yaw, NACA Rep. 1357, 27 pp., 1958.

3013. Yen, K. T., On the thrust hypothesis for the jet flap including mixing effects, AFOSR TN 59-737 (Rensselaer Polytech. Inst. Aero Engng. TR AE 5902), 33 pp., June 1959.

Author discusses theoretically the effects of the viscous mixing of the jet with the surrounding air flow on the thrust of a jet-flapped airfoil.

First, it is shown that the linearized jet flap problem may be separated into a symmetrical part which determines the thrust, and an antisymmetrical one governing the lift generation.

A momentum relation is then written for the thrust, and, further, a boundary-layer-type momentum integral equation is derived which accounts for the mixing of the jet with the external flow.

Finally, an approximate study is made, with the help of the latter equation, on the variation of the jet flap thrust with the deflection angle.

It seems that author had no knowledge of some earlier papers on related subjects [see, for instance, M. Roy, AMR **11** (1958), Rev. 2743].

L. Z. Dumitrescu, Roumania

3014. Maskell, E. C., and Spence, D. A., A theory of the jet flap in three dimensions, *Proc. Roy. Soc. Lond.* (*A*) **251,** 1266, 407–425, June 1959.

The treatment of two-dimensional jet-flapped wings in incompressible flow by the methods of thin-airfoil theory given by one of the authors [AMR **10** (1957), Rev. 2218] has been extended to the case of a thin wing of finite aspect ratio which possesses a deflected jet sheet of zero thickness emerging with a small angular deflection at its trailing edge. The aspect ratio A must be large, its permissible minimum increasing with the jet momentum coefficient C_J. The spanwise variation of loading could be calculated for arbitrary planforms and jet-momentum distributions, but the present paper is confined to the case in which ... the jet-momentum flux per unit span [is] elliptically distributed, the deflection τ and incidence α being constant over the span. The relation between the coefficients of induced drag and lift is then

$$C_{D_i} = C_L^2/(\pi A + 2C_J),$$

induced drag being defined as the difference between the thrust and the (constant) flux of momentum in the jet. The ratio of C_L to the value $C_L^{(2)}$ which it would have in two dimensions is

$$C_L/C_L^{(2)} = \{A + (2/\pi)C_J\}/\{A + (2/\pi)(\partial C_L^{(2)}/\partial\alpha) - 2(1+\sigma)\},$$

where $\partial C_L^{(2)}/\partial\alpha$ is the two-dimensional derivative of lift with respect to incidence, a known function of C_J, and $\sigma = 1 - \alpha_i/(\frac{1}{2}\alpha_{inv})$. An expression for σ is found in terms of known quantities by equating the induced drag calculated from the detailed forces on the wing to that given above. Remarkably close agreement with observed values of C_L is obtained in all cases.

From authors' summary by T. R. Goodman, USA

3015. Iserland, K., Investigations on the reversal of a free air-jet by means of spin (in German), ETH Mitt. Inst. Aero., Zurich, no. 25, 99 pp., 1958.

An important present day problem is the shortening of runways for jet planes by using proper braking methods. A comparison between various possibilities (wheelbrake, parachute, etc.) shows that the reversal of the propulsion jet, so called "jetbrake," provides the most effective method. Paper describes an experimental investigation of exhaust jet spin to assist in thrust reversal.

The characteristic properties of the jet in the incompressible domain and the jet features in the compressible realm were studied on test stands. The necessary airspeeds were provided by a compressor. The suspension of nozzle, thrust tube, and supply line was swinging, which allowed a very accurate means of thrust measurement by use of a balance. The quantity of flow was measured by a diaphragm. The spin in the jet was performed by rotating the blades of the built-in distributor. In the compressible domain a controllable nozzle (gradually changing aperture) was used in order to keep constant pressure in the thrust tube. The streamline pattern and the pressure distribution inside the jet and along the nacelle were determined by wool strings and micropressure-probe respectively.

As a result of the tests it became obvious that a spun airjet provides a very stable and perfect reversal. This may be accomplished either by use of a ring cascade or merely by suction at a rear of the nozzle. In both cases it is typical that, below a certain critical spin angle, the jet coheres due to the negative pressure in its core. Beyond this critical state, however, a sudden and perfect reversal of the jet is achieved. This phenomenon was observed at all applied sizes of nozzles; however the reversal occurred at smaller spin angles on divergent nozzles and larger diameters, compared with cylindrical nozzles and smaller diameters respectively.

In a free jet with a spin distribution such that the core of it is irrotational, the vacuum in the core is sufficient in the subcritical domain to cohere the airjet. In the supercritical case, however, the vortex layer between the spin-effected zone and the irrotational core consumes so much kinetic energy that the pressure in the core becomes less than the ambient atmospheric pressure. Due to this fact ambient air from behind penetrates into the center of the jet and disturbs the radial equilibrium. A ring-jet with a hollow core is developed which expands radially behind the nozzle. In this state the jet reverses very easily. Above the critical spin angle ($\sim 45^\circ$) the jet will spread due to the action of centrifugal force. If a ring cascade or a suction device is present, the jet thrust abruptly jumps from positive to negative values. On the described testing plant negative thrusts up to 57% of the nominal load were achieved.

Reviewers believe that this report treats this kind of jet reversal for the first time.

R. K. Sherburne and W. Kasberger, USA

3016. Moore, T. W. F., A note on the causes of thin aerofoil stall, *J. Roy. Aero. Soc.* **63,** 588, 724–730 (Tech. Notes), Dec. 1959.

3017. Goodman, T. R., and Sargent, T. P., Some evidence justifying the representation of blasts as traveling gusts, *J. Aero/Space Sci.* **26,** 9, p. 608 (Readers' Forum), Sept. 1959.

It is the purpose of this note to show that when a blast wave of any magnitude is represented by a traveling gust and the impulse is computed using apparent-mass concepts, the result is equivalent to accounting for diffraction of the blast wave. Since the familiar lift-growth functions for a traveling gust include apparent-mass effects as well as the circulatory lift growth, these functions are applicable directly to the blast-penetration problem because the diffractive loading has already been taken into account.

From authors' summary

3018. Flodin, K., and Sundstrom, M., Investigation of the response to random wind gusts of a typical subsonic fighter aircraft in level flight with Mach number 0.9 at sea level, Roy. Inst. Technol., Stockholm, KTH Aero. TN 47, 25 pp., 1958.

Frequency spectra (power spectral densities) and root-mean-square deviations are computed for all velocity components, attitude angles, components of displacement, and load factor for an aircraft in level flight during normal turbulence conditions. The turbulence is defined by spectral density curves according to Clementson, Decaulne, and Liepmann. For some of the outputs, the influence of different modifications as to the wind gust spectra has been investigated.

Calculations have been carried out on two assumptions: first, that the wind disturbance is the same all over the aircraft and, second, that the disturbance has a velocity gradient the spectrum of which is that given by Decaulne and Summers.

The aircraft is equipped with attitude stabilizing autopilots in all three control channels. The investigation concerns also the case where all controls are fixed. The airplane considered is fictitious, though with characteristics representative for subsonic fighter aircraft of the same type as, for instance, the Hawker "Hunter."

From authors' summary by L. C. Woods, England

Vibration and Wave Motion in Fluids

(See also Revs. 2687, 2787, 2901, 2948, 2999, 3075, 3102, 3104, 3143, 3148, 3185, 3189)

3019. De Housse, N. M., Approximative method for the calculation of oscillations in a surge tank (in French), *Bull. Centre Etude Rech. d'Essais Scient. Constr. Genie Civ. et d'Hydral. Fluviale* **9,** 339–397, 1957.

This paper deduces a nonlinear total differential equation for unsteady flux of liquid from a reservoir, when the pipe has a surge tank as side branch. The dynamic response is computed for various simple opening and closing operations of the valve at the pipe exit.

S. Corrsin, USA

3020. Flitman, L. M., On a mixed boundary value problem for the wave equation, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **22,** 6, 1185–1191, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

System of equations representing vibrations of elastic fluid is developed under assumption of pressure applied at one point of boundary. The problem is reduced to a two-dimensional one, and the system of equations degenerates into one wave equation. Integration gives a wave propagation picture.

S. Kolupaila, USA

3021. Marks, W., Wave propagation in the tenth-scale model of the maneuvering basin. Part 1, Long-crested regular waves, David W. Taylor Mod. Basin Rep. 1192, 39 pp., Oct. 1958.

A quantitative study was made of long-crested regular waves in the tenth-scale model of the Taylor Model Basin maneuvering basin. The eight wave-makers which constitute one short side of the basin were "balanced" to produce uniform sinusoidal waves. The nature of the wave field, in time and space, was investigated for a variety of wave lengths and wave heights. It is demonstrated that a sufficiently large area of the tank remains homogeneously stationary to satisfy most test conditions. The observance of high-frequency reradiation from the sidewalls of the tank is discussed and remedial measures, based on experimentation, are suggested. It is shown that variable depth and removal of one side barrier do not materially affect wave propagation in the range of wave lengths and wave heights tested. The wave-absorbing beach was found to be highly effective.

From author's summary

3022. Gubkin, K. E., Propagation of discontinuities in sound waves, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **22,** 4, 787–793, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Author uses the method of characteristics in the solution of the equation of gas dynamics describing propagation of waves of small amplitude. The extent of the disturbed region is assumed to be small in comparison with the radius of curvature of the wave front and a characteristic length within which the medium changes perceptibly. The nonlinear properties of the motion, exhibited in effect whenever wave traverses distances substantially greater than the length of the disturbed region, lead to a change in profile of the wave and the development of discontinuities in it. Computation of these nonlinear factors suggests that they have a damping effect on the shock front, in accord with acoustic theory. Results are shown to be in agreement with those of other authors for the case of spherical (or cylindrical) waves propagating in a homogeneous stationary medium.

From author's summary by B. W. Wilson, USA

Fluid Machinery

(See Revs. 2966, 3052, 3091)

Flow and Flight Test Techniques and Measurements

(See also Revs. 2921, 2963, 2991, 2997, 2999, 3015, 3059, 3090, 3101)

3023. Lutz, K., The calculation of the suspended-body flowmeter (in German), *Regelungstech.* **7,** 10, 355–360, Oct. 1959.

The formulas for calculating the characteristics of a variable-area flowmeter are derived from the linear and quadratic resistance laws for bodies placed in a fluid. A table of calibration factors permits the transformation of one formula into the other. This table of calibration factors, which has been established empirically, represents the whole field of characteristics of a variable-area flowmeter and gives information on the behavior of this flowmeter, particularly with regard to the physical properties of the fluid, such as density and viscosity. The calibration scale for any fluid can be calculated from the derived formulas and from the calibration factors, if the dimensions of the particular flowmeter are known. An empirical calibration formerly required is no longer necessary. From author's summary

3024. Dhawan, S., and Vasudeva, B. R., The pitot tube displacement effect in boundary layer flows, *J. Aero. Soc. India* **11,** 1, 1–18, Feb. 1959.

Paper gives a rather complete analytical and experimental treatment of the displacement effect of pitot tubes while making measurements in laminar and turbulent boundary layers. The displacement, ε, is defined as the displacement outward from the wall of the stagnation streamline in the free stream as compared to its position at the pitot entrance.

Approximate analytical solutions are obtained by the linear addition of the potential solution of a uniform flow around a pitot near a wall and the solution of the pitot in an unbounded uniform shear flow. Solutions for two-dimensional cylinders and spheres are given.

Fairly extensive experimental measurements were made for two-dimensional cylindrical, spherical, forward-facing rectangular, finite cylindrical and forward-facing circular pitot tubes. Reasonably good agreement between theory and experiment is indicated. It is shown that, generally, in two-dimensional cases the wall effect is dominant, giving a negative ε, while for three-dimensional pitots the shear effect predominates and ε is positive.

E. K. Parks, USA

3025. Mello-Christensen, E., and Martuccelli, J. R., On the effect of flow discontinuities on oscillatory-pressure measurements in supersonic flow, *J. Aero/Space Sci.* **26,** 9, 601–602 (Readers' Forum), Sept. 1959.

3026. Danckwerts, P. V., Flow measurements with ball meters, *AIChE J.* **5,** 1, p. 134, Mar. 1959.

3027. Patterson, G. N., Theory of free-molecule orifice-type pressure probes in isentropic and non-isentropic flows, Univ. Toronto, Inst. Aerophys. Rep. 41 (Revised), 15 pp., Apr. 1959.

See AMR **11** (1958), Rev. 1350.

3028. Gerrard, J. H., Piezoelectric pressure gauges for use in a shock tube (in English), *Acustica* **9,** 1, 17–23, 1959.

The requirements for a gage for the measurement of pressure at the wall of a shock tube are discussed and previous attempts to meet these requirements are reviewed. Two barium titanate pressure gages are described which have a response time of about 2 μs. The spurious fluctuations in the response following a shock wave have been reduced to small magnitude.

From author's summary

3029. Engl, W., How to determine the "effective area" of disk diaphragm (in German), *Regelungstech.* **7,** 5, 165–168, May 1959.

One side of a disk diaphragm is loaded by a pressure which is opposed by a force acting upon the other side of the disk. As a result the diaphragm is deflected in the direction of the greater pressure. This article shows a method of calculating, for small deflections, the "effective area", that is the area from which, by multiplying it with the pressure, the opposing force can be found. A device is described consisting mainly of a very stiff pressure transducer which at the same time produces and measures the opposing force. From author's summary

3030. Manheimer-Timnat, Y., and Low, W., Electron density and ionization rate in thermally ionized gases produced by medium strength shock waves, *J. Fluid Mech.* **6,** 3, 449–461, Oct. 1959.

The attenuation of 3-cm microwaves by ionized gases in a ½-in. diameter shock tube has been measured in air for the shock Mach range 8.2 to 10.4 and in nitrogen containing 0.25% oxygen for the range 7.4 to 8.8. The theoretical attenuation was calculated from the equilibrium thermodynamic properties of the ionized gases using a theory due to Margenau [*Phys. Rev.* **69,** 508–513, 1946]. Good agreement with the experimental results is claimed. Ionization relaxation times were measured for air and match previous results obtained by Niblett and Blackman using a photographic method [AMR **12** (1959), Rev. 304]. There is no discussion of the ionization mechanism. E. J. Morgan, England

3031. Brogan, T. R., The electric arc wind tunnel—a tool for atmospheric re-entry research, *ARS J.* **29,** 9, 648–653, Sept. 1959.

Paper describes the development and calibration of an arc-powered wind tunnel designed to provide steady flow simulation of the conditions encountered during re-entry. Flight velocities between 16,800 and 21,800 fps can be simulated with this device. The flow properties in the tunnel test section can be determined to a degree of accuracy sufficient for quantitative experiment. Further work now in progress will improve the degree of simulation which can be achieved with arc-powered wind tunnels.

From author's summary by J. Rabinowicz, Israel

3032. Gross, R. A., A high-temperature, steady-flow, supersonic tunnel, *J. Aero/Space Sci.* **26,** 10, 676–677 (Readers' Forum), Oct. 1959.

3033. Howard, W. M., The effect of temperature on pressures measured in a hypersonic wind tunnel, *J. Aero/Space Sci.* **26,** 11, p. 764 (Readers' Forum), Nov. 1959.

3034. Jahn, R. G., and Grosse, F. A., Response of electrostatic probes to ionized gas flows in a shock tube, *Physics of Fluids* **2,** 4, 469–470 (Research Notes), July–Aug. 1959.

Thermodynamics

(See also Revs. 2954, 3030, 3041, 3042, 3071, 3096, 3098, 3104, 3108, 3205)

3035. Kjelland-Fosterud, E., Determination of the viscosity of steam at supercritical pressures, *J. Mech. Engng. Sci.* **1,** 1, 30–38, June 1959.

This paper records the measurement of the viscosity of the water substance at pressures from 200 atmospheres to 1000 atmospheres and at temperatures from 370 to 540C. The viscometer, which is of a capillary type, uses the principle of the falling mercury pellet but is of a special design prepared by the author to meet the extreme conditions under which the observations were to be made. A careful examination has been carried out of the possible sources of error, and the necessary corrections and calibrations are given. At the lower end of the pressure range, at which recent data are extant from other workers, the results are in close conformity with those from the existing sources.

From author's summary

3036. Vargaftik, N. B., and Tarzhimanov, A. A., An experimental investigation into heat conduction of water steam at high temperature and high pressure (in Russian), *Teploenergetika* no. 9, 15–21, Sept. 1959.

Authors present the results of experimental investigations into heat conduction of water steam in the temperature range from 350 to 720C under pressures from 5 to 360 kg/cm^2.

From authors' summary

3037. Suzuki, E., Energy equation of the atmosphere and irreversible reciprocity theorem in statistical mechanics, *J. Meteorol. Soc., Japan,* 75th Anniversary Volume, Nov. 1957; 271–274.

Paper attempts to investigate theoretically the meaning of the so-called "energy equation of the atmosphere" (actually the regular energy equation written for a moving and deforming medium) in the light of Onsager's reciprocal relations valid within the frame of thermodynamics of linear phenomenological relations.

Article starts with a derivation of the entropy production for a thermally conducting frictional fluid. The equations of motion are then written including the Coriolis forces and frictional terms. Author seems confused in the interrelation of frictional forces and the friction-dissipation terms, denoted by ψ, that appear in the expression for the entropy production. He writes: $\psi = \rho(V \cdot F)$ where ρ is the density, F is the frictional force and V is nowhere explicitly defined in the paper.

Author proceeds in writing two linear phenomenological relations, one for the heat flux and the other for V. In the heat flux equation he couples the temperature gradient term with a term containing the frictional force. Thus author ignores Curie's theorem which states that forces of different tensorial character *cannot* be coupled [see S. R. DeGroot, "Thermodynamics of irreversible processes," North-Holland Publishing Company, p. 121].

Reviewer feels that paper is at best obscure and where clear it is incorrect. P. S. Lykoudis, USA

3038. Sherman, B., Heikes, R. R., and Ure, R. W., Jr., Calculation of efficiency of thermoelectric devices, *J. Appl. Phys.* **31,** 1, 1–16, Jan. 1960.

A procedure has been developed for the exact calculation of the efficiency of thermoelectric generators and cooling devices in which the parameters of the materials have arbitrary temperature dependence. High-speed computer techniques are found necessary. Approximate methods are reviewed and their discussion extended. A number of examples are worked out by both the exact and approximate methods. Comparison of these results show that the approximate methods agree with the exact method to about 5% in the case of power generation and to about 15% in the case of the refrigeration coefficient of performance. However, in the case of the maximum heat pumping rate deviations as large as a factor of 2 are found.

From authors' summary by M. J. Goglia, USA

3039. Schlichtig, R. C., and Morris, J. A., Jr., Thermoelectric and mechanical conversion of solar power, *J. Solar Energy Sci. Engng.* **3,** 2, 14–18, Apr. 1959.

It has been frequently demonstrated that solar energy can produce power by its direct heating effect. It has previously been overlooked, however, that sunshine stores vast amounts of free energy in the atmosphere by lowering its relative humidity, particularly in desert areas. The presently described equipment is a composite of a solar collector, a thermoelectric generator, and a mechanical converter which will generate power from waste heat and stored free energy of dry atmospheric air.

The mechanical converter is unusual in its simplicity, its flexibility, and its capability to use small temperature differentials. Although the mechanical converter is described as associated with a reflecting solar collector, field tests may show the mechanical converter to be more practical without the collector, in which case air of the greatest usefulness would be collected from the surface of the solar heated ground by a grid of air ducts. Several cycle variations are possible with the same basic machine, which uses air as the working substance.

Although the use of salt or fresh water for evaporation improves the power output, the mechanical converter will operate without evaporating water if water cannot be obtained.

From authors' summary

Heat and Mass Transfer

(See also Revs. 2682, 2686, 2690, 2712, 2713, 2902, 2921, 2926, 2965, 2968, 2984, 2986, 3031, 3036, 3074, 3075, 3078, 3083, 3087, 3103, 3104, 3127, 3128, 3185, 3187)

3040. Bailey, H. R., Heat conduction from a cylindrical source with increasing radius, *Quart. Appl. Math.* **17,** 3, 255–261, Oct. 1959.

Author considers a problem which arises in connection with secondary oil recovery by an underground combustion process: heat conduction in an infinite homogeneous medium, from the surface of the cylinder of finite length h and of radius r_F increasing with time $r_F = r_F(t)$. The heat source is assumed to be at the surface of the cylinder and is expressed with the help of Dirac's delta function. Explicit solution in integral form is written by use of Green's function. Two special cases of particular practical interest are investigated: (1) the case, when the radius r_F grows with constant velocity $r_F(t) = Ut$; and (2) when $r_F^2 = Vt$.

Under assumption of no vertical losses, a limiting solution of the first case is presented for finite values of $r - Ut$ (that is, for positions near the sources). For the second case (under assumption of no vertical losses, also) an explicit solution is obtained.

K. Rektorys, Czechoslovakia

3041. Zoller, K., The heat conduction equation in the presence of thermal stresses (in German), *Ing.-Arch.* **28,** 366–372, Mar. 1959.

Thermal stresses are conventionally obtained in the following way: the Fourier equation of heat conduction is solved in the form $\rho c T_{,t} = \text{div}(\lambda \text{ grad } T) + W(r, t)$* (here T is the temperature, t is the time, c the specific heat, ρ the density, λ the conductivity, r the position vector and W is the intensity of the spatially distributed heat sources,) subject to suitable boundary and initial conditions. In addition the flux $q = -\lambda \text{ grad } T$ and if $Q = -\text{div } q + W$, (*) may be written as $\rho c_v T_{,t} = Q$. The next step consists in the determination of the thermal stresses under the assumption that the temperature field is known and not coupled to the elastic field equations. This approach ignores the thermal energy associated with the volume changes of an element and F. Neumann (1885) suggested that the equation read $\rho c_v T_{,t} = Q - (\rho/\alpha)(c_p - c_v)(\text{div } u)_{,t}$ (**) where α is the volumetric coefficient of thermal expansion and u is the displacement vector. In Neumann's generalized equation of heat conduction (**) the additional term is the appropriate one for an ideal gas; however an elastic body is acted upon not only by hydrostatic pressure but by shearing forces as well. In view of the newer applications of the field, a more complete presentation of the equations is given by the author based in part on work by C. Truesdell (to be published in the Handbook of Physics, Volume 3, 1). A heat-conduction equation in the form $\rho c(dT/dt) = Q$ is obtainable only in the case that the work of the stress resultants is fully recoverable, and in particular when the stresses do not contain any dissipative parts or when no permanent distortion takes place. The heat-conduction equation remains coupled to the remaining field equations in general and splits off rigorously only in the case of a stationary equilibrium state. These facts, the author concludes, do not exclude the possibility that thermal stresses can be found with good approximation (as before) by considering the solution of the uncoupled heat-conduction equation and then determining the stresses under the assumption that the temperature distribution is known.

F. V. Pohle, USA

3042. Zwikker, C., Physical background of high frequency heating (in Dutch), *Ingenieur* **70,** 43, 127–129, Oct. 1958.

Formulas are derived for the heat evaluation for inductive and capacitive heating, respectively. Inductive heating is computed for a rod surrounded by a cylindrical coil and capacitive heating is computed for a similar rod with circular electrodes placed at the ends of the rod perpendicular to the axis of the cylinder. In this way similar equations are obtained for both methods of heating. The theory is given assuming that the permeability, the dielectric constant, the conductivity and the density of the heated material are constant. A brief discussion is given of the influence of the temperature dependence of these constants.

J. A. Businger, USA

3043. Visvanathan, S., and Sanghi, I., Relationship between heat conductivity, molecular weight, and freezing point of liquids (in English), *Naturwissenschaften* **46,** 23, p. 647, Dec. 1959.

3044. Larson, H. K., Heat transfer in separated flows, *J. Aero/Space Sci.* **26,** 11, 731–738, Nov. 1959.

Heat transfer for equivalent attached and separated laminar and turbulent boundary layers on axially symmetric and on two-dimensional bodies was measured in wind tunnel through Mach number range from 0.3 to 4.0 and Reynolds number range from 10^6 to 4×10^6. Average heat transfer for separated laminar layers was about 0.56 of that for equivalent attached layers independent of Mach and Reynolds numbers; for separated turbulent layers ratio was about 0.60 at Reynolds number of 3×10^6 over Mach number range from 0.3 to 4.0. For turbulent boundary layers the reduction in heat transfer caused by separation increased with increase in Reynolds number. Experimental results were compared with theory of NACA TN 3792. Experimental data show that increase in Mach number increases and reduction in wall temperature decreases length of laminar flow in separated region. Local heat-transfer measurements over length of separated regions show a maximum in reattachment region; maximum is greater than attached flow value at same point.

N. Tetervin, USA

3045. Stojanovic, D., Similar temperature boundary layers, *J. Aero/Space Sci.* **26,** 9, 571–574, 591, Sept. 1959.

Author finds the conditions for the existence of "similar" solutions of the temperature equation for a fluid of constant physical properties, corresponding to the "similar" incompressible velocity boundary layers discussed earlier by Schuh [50 Jahre Grenzschichtforschung, pp. 147–152, 1955] for two-dimensional, unsteady motion and by Geis [same book, pp. 294–303] for steady rotating flow about a body of revolution. Viscous heating is included.

The only new numerical work is the calculation of the temperature distribution in rotating flow over a fixed plane, when the wall temperature is constant and viscous heating is ignored. Reviewer points out that the calculation utilizes Bödewadt's flow calculation, rather than the more accurate calculation of Browning [see Schlichting, "Boundary layer theory," Pergamon Press, London, 1955, p. 158].

J. T. Stuart, England

3046. Nakamura, K., Fukunaga, S., Sawada, T., Matusita, M., and Kamo, N., Researches on new heat transmitting tubes (1st report), *Bull. JSME* **2,** 7, 376–381, Aug. 1959.

Paper is a summary of a series of investigations into forced convection heat transfer from air to circular tubes. Tubes have either one or two axial fins fixed to outer surface. The relative angular position of the fins is one of the variables in experiments on two-fin tubes.

For flow normal to one of these tubes, a 50% increase in overall heat transfer (compared with a plain tube) occurs when fins, 10 mm deep, are inclined at 40 deg to each other, are on the upstream side of tube, and are symmetrical about direction of air flow. Air velocity is varied from 3 to 9 m/sec.

Such tubes, arranged in staggered banks of four rows, also show increased heat transfer and decreased pressure loss over plain tubes, similarly spaced. Transverse pitch is 80 mm and longitudinal pitch is 60, 80 or 100 mm. Two-fin tubes with 40 deg and 180 deg inclination have similar heat-transfer coefficients. Air velocity range is 4 to 12 m/sec.

The tube bundle configuration adopted is not the optimum for plain circular tubes.

T. D. Patten, Scotland

3047. Johnson, D. S., Velocity and temperature fluctuation measurements in a turbulent boundary layer downstream of a stepwise discontinuity in wall temperature, *ASME Trans.* **81E** (*J. Appl. Mech.*), 3, 325–336, Sept. 1959.

Results are presented of an experimental investigation of the coexisting thermal and velocity fluctuation fields in a turbulent boundary layer downstream of a small stepwise discontinuity in wall temperature. The statistical behaviors of several relevant fluctuating quantities have been obtained at a typical cross section of the boundary layer in the region where the thermal boundary layer has not yet reached the free stream. The instantaneous surface of demarcation between heated and unheated fluid was found to be sharp and distinct at all points, resulting in intermittent temperature fluctuation signals well within the fully turbulent region of the momentum boundary layer. From the measurements at one section, the balances of turbulent kinetic energy and of turbulent temperature fluctuations across the boundary layer have been evaluated. In addition, the distribution of the local turbulent Prandtl number (ratio of the turbulent diffusivities of momentum

and heat) through the boundary layer has been obtained; it is not constant and varies between limits of 0.8 and 1.2.

From author's summary by M. S. Uberoi, USA

3048. Knott, R. F., Anderson, R. N., Acrivos, A., and Petersen, E. E., An experimental study of heat transfer to nitrogen-oil mixtures, *Indust. Engng. Chem.* **51,** 11, 1369–1372, Nov. 1959.

These results are of interest to the design engineer confronted with the problem of predicting heat-transfer coefficients to two-phase mixtures. From authors' summary

3049. Hartnett, J. P., Heat transfer from a nonisothermal disk rotating in still air, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 672–673 (Brief Notes), Dec. 1959.

The present note examines the influence of a variation in the surface temperature on the heat transfer from a disk rotating in still air, allowing the temperature difference between the disk surface and the fluid at rest to vary as a power function of the radius. From author's summary

3050. John, R. R., and Bade, W. L., Stagnation point heat transfer in a subsonic jet of arc-heated air, *ARS J.* **29,** 7, 523–525 (Tech. Notes), July 1959.

Heat transfer from a free subsonic jet of arc-heated air to the stagnation region of a plane surface has been determined experimentally. The enthalpy, pressure and velocity gradient of the flow at the edge of the boundary layer were estimated on the basis of mass flow and energy balance measurements. Heat flux values predicted by a correlation formula for stagnation point heat transfer in dissociated air agree approximately with the experimental values. From authors' summary

3051. Lay, J. E., An experimental and analytical study of vortex-flow temperature separation by superposition of spiral and axial flows, Part II, *ASME Trans.* **81**C (*J. Heat Transfer*), 3, 213–222, Aug. 1959.

For Part I, see AMR **11** (1958), Rev. 5043.

Part 2 reports on the analytical study. The free vortex motion of the gas upon entrance to the tube is mathematically superposed to a compressible sink to give a spiral flow in the plane. The characteristic existence of limit circles is corroborated by the experimental flow visualization. The solution in space is obtained by addition of a uniform axial velocity to the spiral flow. When viscosity effects are considered, the free vortex is shown to change into a forced vortex. The latter flow is one of minimum kinetic energy and maximum entropy. Energy considerations enable the determination of an optimum cold air radius to give largest stagnation temperature separation. Significantly, this was the radius that gave best performance in the experimental program. From author's summary

3052. Zysina-Molozhen, D. M., Approximate method of analysis of heat transfer to turbine blades (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 10, 28–35, Oct. 1957.

Author attempts by a combination of analytic and semiempirical relations to derive some simplified method for a rapid estimate of heat transfer in cascades. The approach consists in relating basic energy conservation laws at several stations of cascade by means of an elementary perturbation method. The perturbation parameter is the thermal or momentum boundary-layer thickness which serves for establishing a linear relation between flow parameters in front of and behind the cascade. The analytical development leads to a dimensional heat-transfer correlation involving the geometric parameters of the cascade and also velocities at the trailing edges and downstream, thermal boundary-layer thickness and temperatures of the stream and of blade wall. In order to evaluate the thermal boundary-layer thickness a variety of experimental and curve-fitted relations is used, obtained from various unrelated experiments. Eventually an expression is obtained for the thermal boundary-layer thickness which depends on the nature of flow (laminar or turbulent) within the cascade and on various flow and shape parameters.

Reviewer believes that paper is an exercise in elementary mathematical analysis without much relevance to practical applications. For example, a great many assumptions are not stated and author does not hesitate to apply results valid for incompressible flow to that of compressible one, and conversely. A number of local flow and thermal parameters appear in heat-transfer expressions for the entire cascade without indication of how to evaluate their average values. Some shape coefficients appear in correlations derived from a single test without regard to the fact that, for different cascades, they would have different values. Under practical conditions of operation it is difficult to predict the actual character of the boundary layer over the span of the blade which is necessary for author's correlation formula. Reviewer believes that the basic energy conservation law on which the discussion of this paper is based is not adequate for practical turbomachinery where the cascade is rotating, since the work term resulting from the rotation is missing.

No specific comparisons with experiment are made except for one isolated case where the author states merely that there is some agreement between his theoretical results and some measurements made in England. In view of many inconsistencies in this paper, this reviewer feels that such agreement is fortuitous. It should be pointed out that this paper was written some time around 1955 and that a great deal of literature has been unclassified in the meantime which treats the problem of heat transfer in cascades in a meaningful fashion.

B. Zarwyn, USA

3053. Cess, R. D., and Shaffer, E. C., Summary of laminar heat transfer between parallel plates with unsymmetrical wall temperatures, *J. Aero/Space Sci.* **26,** 8, p. 538 (Readers' Forum), Aug. 1959.

3054. Vickers, J. M. F., An usual flow pattern may explain the behavior of heat transfer coefficients between fluid jets and normal surfaces, *Indust. Engng. Chem.* **51,** 8, 967-972, Aug. 1959.

3055. Saelman, B., Integration of some thermal differential equations, *J. Aero/Space Sci.* **26,** 11, 754-755 (Readers' Forum), Nov. 1959.

3056. Kutateladze, S. S., Borishanskii, V. M., and Novikov, I. I., Heat transfer in liquid metals, *J. Nuclear Energy* **9,** 1/4, 214-229, June 1959.

Because of their high thermal conductivity, liquid metals are well suited for engineering applications where high rates of heat transfer are desirable. The paper reviews and compiles work of various authors on the subject of heat transfer between solid surfaces and flowing liquid metals.

Experimental data and empirical formulas presented for heat transfer to liquid metals include that for flow: in long and short tubes, in annuli and flat apertures, longitudinally through a bundle of rods, transversely around cylinders; also for free convection, during condenstaion of metallic vapors and during the boiling of liquid metals.

Reviewer believes the paper fills a gap for a comprehensive reference needed by engineers in fields involving heat transfer calculations between solids and liquid metals.

A. H. El-Waziri, USA

3057. Fujii, T., Mathematical analysis of heat-transfer from a vertical flat surface by laminar free convection, *Bull. JSME* **2,** 7, 365-369, Aug. 1959.

Title problem is attacked by integral method. For constant wall temperature, velocity and temperature functions are chosen in form $s\eta e^{-s\eta}$, and $(1 + \frac{1}{2}\eta)\, e^{-\eta}$ respectively. s depends on Prandtl number; η is normalized distance from wall. Extension is made to variable wall temperature case. Results agree well with available solutions obtained by more involved procedures.

M. Finston, USA

3058. Golubenkov, V. N., Thermal convection in a rotating circular pipe with a constant temperature gradient (compressible fluid), *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **22,** 6, 1205-1207, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Assuming small variations in temperature, velocity, pressure and density, author solves the differential equation of the problem in terms of a power series of the constant temperature gradient at the wall of the rotating pipe. The first approximation of the solution contains two terms; the first represents the free convection, the second the forced motion of the fluid due to the external pressure difference.

K. Pohlhausen, USA

3059. Eggers, A. J., Jr., A method for simulating the atmospheric entry of long-range ballistic missiles, NACA Report 1378, 7 pp., 1958.

This report is a reprint of NACA Research Memo RM A55I15. It gives an analysis of temperature and stress simulation of reentry problems by shooting models from a hypervelocity gun upstream through a wind tunnel Laval nozzle which is shaped in such a way that the desired time-Mach number-density relationship is obtained.

The fact that the report was issued three years after the Research Memo without any changes or additions seems to indicate that the author did not continue his studies on the subject. Thus all open questions, e.g., simulation of burning characteristics, fracture processes (though thermal deformation should be simulated quite well) and other detail items still need clarification.

H. J. Ramm, USA

3060. John, R. R., and Recesso, J., Ablation characteristics of a subliming material using arc-heated air, *ARS J.* **29,** 9, 663-665 (Tech. Notes), Sept. 1959.

A procedure is described indicating the use of arc-heated air in the determination of a material's ablation characteristics. Experimental results are reported for Teflon. The results are interpreted in terms of a simplified ablation theory.

From authors' summary

3061. Papell, S. S., and Trout, A. M., Experimental investigation of air film cooling applied to an adiabatic wall by means of an axially discharging slot, NASA TN D-9, 64 pp., Aug. 1959.

An experimental investigation was made to determine the characteristics of axially discharging single-slot film cooling of an adiabatic wall exposed to a hot-air stream. Mainstream gas temperature ranged from 520° to 2000° R and the mainstream Mach number was varied from 0.15 to 0.70. Cooling-air temperatures ranged from 540° to 870° R and the cooling-air Mach number was varied from 0.0 to 1.0. Basic film-cooling-data plots for the four slot heights investigated (1/2, 1/4, 1/8, and 1/16 in.) have been presented in nondimensional form. A data correlation covering the range of effective temperature ratios from 0.1 to 1.0 was obtained using four variations of a basic correlating equation. The four equations and their limitations have been included.

From authors' summary

3062. Spalding, D. B., Adiabatic wall temperature due to mass transfer cooling with a combustible gas, *ARS J.* **29,** 9, 666-668 (Tech. Notes), Sept. 1959.

3063. Scott, R. F., Freezing of slurry around piles in permafrost, *Proc. Amer. Soc. Civ. Engrs.* **85,** SM 4 (*J. Soil Mech. Foundations Div.*), 1-10, Aug. 1959.

In Arctic construction, piles are frequently placed in drilled holes in permafrost and held in position while a slurry of sand or silt and water is poured into the annular space around them. This slurry, under the influence of below-freezing temperatures in the surrounding ground, eventually freezes. The paper presents an analysis of the problem involved in predicting the time that a slurry will take to freeze in particular conditions. The problem was solved by means of an electronic analog computer, and curves of the solution are presented.

From author's summary

3064. Hirano, F., and Nishikawa, K., Time variation of nucleate boiling heat transfer of water, *Bull. JSME* **2,** 7, 370-375, Aug. 1959.

Experiments are described in which water is boiled at atmospheric pressure from regularly grooved surfaces. A parameter ζ is defined by

$$\zeta = \alpha R/\Delta\theta^2$$

where α is the coefficient of heat transfer, R the radius of the heating surface and $\Delta\theta$ the temperature difference between heating surface and boiling liquid. This is taken to be a measure for the "bubble formation ability" and the change of its value with time is found to be of the nature of an exponential decay. Small amounts of fatty acids given by $C_nH_{2n}0_2$ where the integer n varies between 6 and 18 are rubbed into the surface and it is found that the initial value of ζ varies in a regular fashion with n closely paralleling the dependence of the contact potential with n, while the exponent of time decay remains unchanged, and is also independent of heat flux, surface quality and presence of solute, unless scale deposits are produced. Authors conclude that the time variation of ζ is caused by desorption of adsorbed gas from the freshly polished heating surface into the liquid.

P. Savic, Canada

3065. Chambre, P. L., Nonlinear heat transfer problem, *J. Appl. Phys.* **30,** 11, 1683-1688, Nov. 1959.

This report considers a class of heat conduction problems arising in high-speed flight in which the linear conduction equation is subject to nonlinear boundary conditions. An important factor in such boundary conditions is radiation, hence the title which may be somewhat misleading. The report is divided into two parts: (1) Time-dependent temperature distributions in radiating solids, and (2) Radiative heat transfer in high-speed free molecular flow.

Since the equation is linear, the temperature distribution can be found from the surface temperature by Duhamel's integral. The report deals mainly with the calculation of the surface temperature as the solution of a nonlinear singular integral equation. An extensive and very clear discussion of the properties of the integral equation is given. A numerical scheme, utilizing a high-speed computer, for obtaining solutions is described and a number of problems worked out.

The second part gives a summary of the conventional theory of heat transfer to bodies in free molecular flow and considers the temperature distribution in a number of configurations subject to a combination of radiation and free molecular heat inputs.

Reviewer considers this an important contribution but suggests that readers also consult the work of Goodman [AMR **12**(1959), Rev. 4095] for an alternate approach. W. Squire, USA

3066. Abarbanel, S. S., On some problems in radiative heat transfer, AFOSR TN 59-531 (Mass. Inst. Technol., Fluid Dynamics Res. Group Rep. 59-1; ASTIA AD 216 538), 205 pp., Apr. 1959.

The problem is that dealt with in the preceding review. An iterative scheme is presented for solving the singular integral equation for the surface temperature utilizing a change of variable and application of Gauss' quadrature formulas. An interesting discussion is given of the relation of the integral equation method and approximate methods such as Goodman's [AMR **12**(1959), Rev. 4095].

Reviewer is not qualified to judge the relative merits of the present numerical scheme and that proposed by Abarbanel on the basis of the material in the papers.

W. Squire, USA

3067. Kerr, D. L., Radiator areas of thermopile generators in space, *Aero/Space Engng.* **18,** 9, 57-62, 66, Sept. 1959.

Consideration is given to a space-vehicle power plant consisting of a thermopile generator and a radiating surface. Waste heat from the thermopile generator is radiated out to space. An expression is evolved which relates the useful power output per unit radiator area to the operating temperatures and to the electrical and thermoelectrical properties of the material. It is found that corresponding to a given hot junction temperature and to given materials properties, there is an optimum cold junction temperature which gives a maximum power output per unit radiator area.

E. M. Sparrow, USA

3068. Farber, E. A., Selective surfaces and solar absorbers, *J. Solar Energy Sci. Engng.* **3,** 2, 9–13, Apr. 1959.

This paper deals with the emission characteristics of the sun and artificial radiation sources, the absorbing and transmitting properties of materials, and how these properties of materials can be analyzed and used to advantage in solar energy collectors. The actual performance of these surfaces is predicted from spectral data and then compared with actual results obtained with artificial sources indoors and the sun as source outdoors.

From author's summary

3069. Robinson, N., and Stotter, A., A proposed standard test code for the determination of the efficiency of solar water heaters of the flat collector type, *J. Solar Energy Sci. Engng.* **3,** 2, 30-33, Apr. 1959.

The properties which must be considered in obtaining an objective estimate of the quality of a flat-plate-type solar water heater are listed. Methods are given for calculating the aerial, orientation, and thermal efficiency of the heater and the heat storage coefficient. A test procedure is outlined for making an objective standard determination of the efficiency of the heater, and a standardized sheet form is given on which the results can be tabulated.

From authors' summary

3070. London, A. L., Biancardi, F. R., and Mitchell, J. W., The transient response of gas-turbine-plant heat exchangers—regenerators, intercoolers, precoolers, and ducting, *ASME Trans.* **81** A (*J. Engng. Power*), 4, 433-448, Oct. 1959.

The transient response of heat exchangers—particularly the effect on outlet fluid temperature of changes in inlet fluid temperature—is studied by the combination of an electromechanical analog computer and analytical solutions for those cases which have yielded to attack. The paper is concerned chiefly with gas turbine plant where the capacity ratio of the fluids is zero or unity and where the wall-to-fluid-capacity ratio is high, but the solutions presented will be useful to all types of heat exchangers, providing—as one is warned in the paper—that care is taken in interpolation in view of the large number of independent parameters involved.

The results are presented by a series of graphs in which a set of nondimensional parameters, chosen to tie in with those used in describing steady-state conditions in heat exchangers, are used. It is sometimes a little difficult to discover which results spring from the analytical equations discussed and which are a result of the analog computer. It might have been prefereble to have justified the data from the analog by the analytical work and then presented the analog data in a form suitable for design purposes with further elaboration.

The paper succeeds in providing, however, both a useful commentary and summary on the analytical solution of these transient equations and, helped by a useful table summarizing the data presented, information for design purposes.

G. G. Thurlow, England

Combustion

(See also Revs. 3018, 3040, 3091, 3092, 3104)

Book—3071. Lutz, O., and Lohse, W., I-S chart for air and combustion gases [IS-tafel für Luft und Verbrennungsgase] 2nd ed., Berlin, Springer-Verlag, 1959, 18 pp. + nomograms, DM 14. (Paperbound)

This is a new and up-to-date second edition of the Mollier (enthalpy/entropy or I/S) diagram first produced by Lutz and Wolf in 1938. The new version is large (35" × 48"), and well-printed on heavy paper. It is accompanied by a descriptive booklet, which also contains an excellent discussion on the precision attainable, and provides facility for estimating or avoiding the errors. There are also examples worked out in some detail.

Ranges in the main coordinates are: entropy (abscissa) -3 to 19 kcal/kmole-degree and enthalpy −620 to 15,000 kcal/kmole; both are linear scales of course and refer directly to 1 kmole of dry air. The zeros of the units correspond to N.T. P. Isopleths are provided of pressure (range 0.001 to 30 kg/cm^2), temperature (−100 to 1800 C), and specific volume of dry air (1.6 to 40,000 m^3/kmole). A red overprint of isopleths of a quantity β, and an auxiliary ordinate scale permit the study of gases of combustion of arbitrary composition. Lutz' factor β represents the thermal characteristics of the gas. A simple conceptual definition of β is not given; it is a pure number which can be computed readily from the variation of the isobaric heat capacity with temperature, or more easily β can be calculated by an empirical formula from the composition of the gas after combustion (i.e. from the volume fractions of CO_2, O_2, N_2 and H_2O). In addition, a small chart, printed beside the main one, permits the rapid evaluation of β. By definition, $\beta = 1$ for dry air and 1.5 for a "normal" hydrocarbon (85% carbon, 15% hydrogen). Adiabats of dry air are of course vertical straight lines; the adiabat for a given gas mixture through any point A in the chart is constructed by drawing through A a curve parallel to that portion of the proper β-isopleth which intersects the isobar of A. Changes in the enthalpy I for a given value of β are read from the auxiliary ordinate scale.

Dissociation is negligible for dry air under the conditions of the chart. But for gases characterized by higher values of β it may be allowed for by interpolating between a set of β-lines, one drawn for infinite pressure (no dissociation), and others for p = 10, 1, and 0.1 kg/cm^2. A simple chart is available for finding the molecular weight M for the gas mixtures; alternately it can be estimated from an equation. Another aid is a nomogramm, also beside the main chart, for deducing the speed (in m/sec) corresponding to a given enthalpy change.

All in all, a neatly laid-out and very useful graphical aid. The German text is a bit over-scholarly.

W. Hitschfeld, England

3072. Sarrat, P., Measurement of ignition delays at simulated altitudes in rockets using liquid propellants (in French), *Rech. Aéro.* no. 62, 15–25, Jan.–Feb. 1958.

The effect of pressure on the ignition delay of various liquid rocket fuels has been measured in a small-scale experimental rocket combustion chamber. Fuels used include mixtures of triethylamine with turpentine and methylalcohol with nitric acid. The fuel and oxidant composition was varied. The ignition delay times were deduced from oscilloscope records of chamber pressure rise and luminosity detected by a photocell. The recorded values of ignition delay from the small-scale rocket chamber as a function of fuel proportions and composition, and pressure are in reasonable agreement with values obtained from laboratory scale tests. Details are given of the combustion chamber construction and also the various electrical circuits used for instrumentation.

N. P. Moore, England

3073. Gol'denberg, S. A., and Pelevin, V. S., Effect of pressure on the speed of flame propagation in a turbulent stream, *ARS J.* **29,** 10, 765–768 (Russian Supplement), Oct. 1959.

The dependence of the speed of turbulent flame propagation on pressure has been determined using a cylindrical burner with a stabiliser flame ring around the orifice. Pressures varied from 760–100 mm mercury, and Reynolds number flame speed increased with decreasing pressure, the pressure exponent being −0.24 to −0.28. Authors have found similar pressure dependence for laminar flames. At constant flow velocity, reduction in pressures causes increase in flame speed, the pressure exponent being 0.45. From a theoretical analysis of results, authors conclude that pressure effect is due to change in those turbulence characteristics which depend on the kinematic viscosity of the medium. For cylindrical burns Reynolds number is such a characteristic, while for isotropic turbulence produced by screens, Reynolds number is replaced by the fluctuating velocity.

M. F. Hoare, England

3074. Sundukov, I. N., and Predvoditelev, A. S., Flame propagation in two-phase mixtures, Seventh Symposium (International) on Combustion, London and Oxford, Aug. 28–Sept. 3, 1958; New York, Academic Press, 1959, 352–357.

If the fuel drops in combustible mixture do not have sufficient time to evaporate before they are ignited, the burning mixture will be a two-phase system consisting of vapor and liquid drops. The velocity of flame propagation in such a system will be greatly affected by the presence of liquid phase. The flame velocity in a heterogeneous mixture was measured and the proportion of liquid phase to the total amount of gasoline in the mixing chamber was determined by a specially made device. Experimental data show that the flame velocities in two-phase mixture do not fall so steeply as in a homogeneous mixture when the fuel-air ratio decreases.

The authors theoretically derived the flame velocity, regarding it as a velocity of the thermal front traveling along a chain of drops. For that purpose they solved the equation of thermal conduction in the vicinity of the discontinuous thermal front, assuming that the temperature conductivity is constant and the reaction rate is a function of fuel-air ratio only. The solution leads to the conclusion that the cube of flame velocity is proportional to the product of temperature conductivity and reaction rate. Setting the solution against the experimental results, authors conclude that the reaction rate can be represented by a quadratic expression of the fuel-air ratio.

H. Jinno, Japan

3075. Eckhaus, W., On the stability of laminar flame fronts, AFOSR TN 59-562 (Mass. Inst. Technol., Fluid Dynamics Research Group Rep. 59-4; ASTIA AD 216 757), 94 pp., May 1959.

Present stability analysis differs from earlier treatments by considering finite thickness of flame front, taking influence of heat conduction and diffusion explicitly into account. The following simplifications are introduced: diffusion analysis considers only three components (two reactants and one product); only terms linear in flame thickness are retained; effect of chemical kinetics is lumped into linear relation between burning velocity and burned-gas temperature, with undetermined proportionality factor.

First-order perturbation analysis yields more complicated dependence of burning velocity on flame structure than assumed in previous treatments. Burning velocity depends not only on flame front curvature but also on convergence of flow field, and adjusts to changes with finite relaxation time. Introduction of this result into stability treatment shows that, depending on values of two parameters, flame front may: (1) be unstable for all disturbance wavelengths; (2) have one unstable range above a critical wavelength, (3) have two unstable ranges, one above and one below certain critical wavelengths.

In spite of the fairly drastic simplifying assumptions, reviewer regards this work as a significant advance in understanding of flame front dynamics.

G. H. Markstein, USA

3076. Mechanism of Combustion Reactions, Part I, Seventh Symposium (International) on Combustion, London and Oxford, Aug. 28–Sept. 3, 1958; New York, Academic Press, 1959, 1–204.

Thirty-one papers were presented for review. They are divided into five groups:

A. Hydrogen-oxygen reaction
B. Attainment of equilibrium in combustion reactions
C. Mechanism of combustion reactions—nonhydrocarbon
D. Mechanism of combustion reactions—hydrocarbons
E. Inhibition of oxidation reactions

All papers are listed by title, author and number below. References in discussion are by number.

1. Reactions of hydrogen atoms with oxygen. *B. deB. Darwent and V. J. Krasnansky*
2. The slow reaction and second limit of the hydrogen-oxygen reaction in boric acid coated vessels. *R. R. Baldwin and L. Mayor*
3. The mercury photosensitized hydrogen-oxygen reaction at low oxygen concentrations. *J. S. Watson*
4. Production of hydrogen peroxide in reacting mixtures of hydrogen and oxygen. *J. W. Linnett and C. P. Tootal*
5. The rate and mechanism of the thermal dissociation of oxygen. *K. F. Herzfeld*
6. On some reactions occurring during the explosion induction period. *V. V. Voevodsky*
7. Reactions of some radicals and their concentration in flames. *V. N. Kondratiev*
8. Further studies of induction periods in mixtures of H_2, O_2 and NO_2. *P. G. Ashmore and B. P. Levitt*
9. Reactions of atomic oxygen and atomic nitrogen with oxides of nitrogen. *F. Kaufman and J. Kelso*
10. Effect of oxygen on thermal decomposition of nitric oxide at high temperatures. *F. Kaufman and L. J. Decker*
11. Recent studies of the oxidation and decomposition flames of hydrazine. *P. Gray and J. C. Lee*
12. Mechanism involved in the photochemically initiated combustion of H_2S. *A. P. Zeelenberg*
13. First limit induction time studies of CS_2–O_2 explosions. *F. R. Taylor and A. L. Myerson*
14. A study of vibrational relaxation in carbon monoxide by shock waves and infrared emission. *M. Windsor, N. Davidson and R. Taylor*
15. On the perturbation of the vibrational equilibrium distribution of reactant molecules by chemical reactions. *K. E. Shuler*
16. On the analysis of re-combination reactions in an expanding gas stream. *F. T. Smith*

17. Shock tube studies of reaction kinetics of aliphatic hydrocarbons. *H. S. Glick*
18. The point of attack in hydrocarbon oxidation—I: Propane. *R. Burt, C. F. Cullis, R. Larsen and G. J. Minkoff*
19. Products of cool flame oxidation of propane-2-^{13}C. *R. E. Ferguson and C. R. Yokley*
20. Some problems of elementary reactions in gas-phase slow combustion. *Z. G. Szabó*
21. Rate constants of elementary reactions in hydrocarbon oxidation—Low temperature oxidation of lower hydrocarbons. *J. H. Knox*
22. Rate constants of elementary reactions in hydrocarbon oxidation—Competitive oxidation of lower hydrocarbons. *J. H. Knox, R. F. Smith and A. F. Trotman-Dickenson*
23. Application of radioactive isotopes to study the mechanism of some oxidation processes. *D. Gal, F. Dutka, L. Guczi and I. Kende*
24. Some processes in gaseous slow combustions. Formation of carbon monoxide and carbon dioxide. *G. Skirrow and C. F. H. Tipper*
25. On high-temperature oxidation of methane. *G. I. Kozlov*
26. A mass spectrometric investigation of the methane-oxygen reaction at low pressures. *D. J. Fabian and W. A. Bryce*
27. Kinetics and mechanism of methane oxidation. *N. S. Enikolopyan*
28. Inhibition of diethyl ether-oxygen flames by aliphatic amines. *D. J. Waddington*
29. Stabilization by aliphatic amines of free radicals in oxidation systems. *C. F. Cullis and B. A. Khokhar*
30. Mechanism of combustion inhibition by compounds containing halogen. *W. A. Rosser, H. Wise and J. Miller*
31. Effects of surfaces on combustion of methane and mode of action of anti-knocks containing metals. *D. E. Cheaney, D. A. Davies, A. Davis, D. E. Hoare, J. Protheroe and A. D. Walsh*

A. Hydrogen-Oxygen Reaction

Five papers (1, 2, 3, 4, 8) are concerned with this reaction, which is considered to be understood and is often used to illustrate chain reactions. But "understood" means much less than is required for use in aerothermochemical problems such as fundamental flame studies.

Although the three explosion limits are qualitatively understood, exact mechanisms of reaction are not clear, and rates of most of the proposed elementary reaction steps have not been measured.

Three papers (1, 2, 4) contribute to the understanding of the second explosion limit, which is believed to occur when the rate of the three-body combination of H and O_2 to form HO_2 equals the rate of the gas-phase branching reaction

$$H + O_2 \longrightarrow OH + O$$

Darwent and Krasnansky's (1) experiments result in estimates of rate constants for the combination reaction and an estimate of the life of HO_2* as 1.1×10^{-11} sec. Baldwin and Mayor (2) observe a new surface effect at the second limit of boric acid coating, which may indicate a surface branching reaction. Linnett and Tootal's (4) measured hydrogen-peroxide concentrations near the second limit suggest that this substance may be produced from HO_2.

Watson's (3) work clarifies the propagation reactions.

Ashmore and Levitt's (8) experiments uphold the postulate that length of induction period for ignition of hydrogen mixtures in the presence of NO_2 depends on the removal of NO_2 by reaction with hydrogen.

B. Attainment of Equilibrium in Combustion Reactions (Papers Nos. 5, 7, 14, 15, 16)

The concentration of free radicals in flames is in excess of equilibrium, and equilibrium may not be attained during the expansion of hot gases through a nozzle. To explain these observations, knowledge of the interchange of energy between external degrees of freedom (translation) and internal degrees of freedom (rotation and vibration) for molecules involved in combustion reactions is important. Also, the rates of elementary chemical reactions replace equilibrium constants in considering the experiments.

Smith's (16) paper examines reactions in a nozzle which are neither frozen nor followed. He shows the difficulty of handling the problem analytically and points out the significance. This paper emphasizes the practical necessity for understanding details of reactions.

Windsor, Davidson and Taylor (14) used a new shock-tube method to measure vibrational relaxation times for CO between 1400 K and 3000 K. They report longer relaxation times than have been previously reported; i.e., 2200 K, 150μ, compared to 10μ. The increase is attributed to a reduction in impurities such as H_2O and CO_2, which are shown experimentally to have a marked effect on the relaxation time of CO.

Shuler (15) concludes, for reactions represented as a small leak from a large pool, (time scale for transformation of reactant to products is long compared with time scale for the relaxation of the initial distribution) that the perturbation of the vibrational equilibrium distribution is sufficiently small to justify use of equilibrium theories of chemical kinetics. On the other hand, when time scale for transformation of reactant to products is comparable with time scale for the relaxation of initial distribution, the effect of the chemical reaction may be important. The situation may occur in high-temperature chemical reactions.

Both Kondratiev (7) and Herzfeld (5) consider correspondence of measured and calculated elementary chemical reaction rates. Herzfeld's quantum theoretical calculations of rate of dissociation of oxygen molecules gives values for rates which are low by a factor of 170 compared to experimental values. On the other hand, Kondratiev reports the dissociation constant of bromine molecules calculated by Nikitin's quantum statistical calculations to be in good agreement with the empirical formula of Palmer and Horning [*J. Chem. Phys.* **26,** p. 98, 1956]. The difference in methods of calculation is that Nikitin's calculation allows for deviation from the Boltzman distribution and includes the effect of rotation.

In discussion Prof. Crawford pointed out that Shuler's paper shows that the effect of deviation from the Boltzman distribution should be small, and previously Shuler and Herzfeld have indicated that the contribution of rotational energy transfer is small. So the difference in correspondence of calculated and measured rates between the two sets reported is difficult to reconcile.

Jost suggested that the true decomposition of oxygen goes through ozone so that the reaction mechanism used by Herzfeld for calculation does not correspond to the reaction as measured.

The problem was not sufficiently well resolved by discussion to allow the conclusion that calculated reaction rates for thermal decomposition reactions can be substituted for measured rates in studying combustion mechanisms.

C. Mechanism of Combustion Reactions—Nonhydrocarbons (Papers Nos. 6, 9, 10, 11, 12)

Voevodsky (6) proposed a new reaction to explain the observed effect of water on the induction period of the hydrogen-oxygen reaction

$$HO_2 + H_2O \longrightarrow H_2O_2 + OH$$

There was some disagreement as to the requirement for this reaction, showing again that combustion kinetics is inadequate because of the lack of knowledge of intermediates and elementary processes.

Kaufman and Kelso (9) applied their chemiluminescence method to a study of rate constants for reactions of atomic oxygen and nitrogen with oxides of nitrogen.

Kaufman and Decker (10) studied the O_3-NO at temperatures up to 1690 K. Results, explained by a simple mechanism, are in agreement with available rates of atom reactions.

One way in which flame reactions may differ from low temperature reactions is the possibility of thermal decomposition occurring before oxidation. Gray and Lee (11) conclude that for hydrazine flames pyrolysis does not precede oxidation for O_2 and NO as oxidants, but the evidence is not completely conclusive.

Two papers were concerned with the combustion of carbon disulfide. Flash photolysis study by Zeelenberg (12) resulted in first proposed reaction mechanism based on observed intermediates.

D. Mechanism of Combustion Reactions—Hydrocarbons (Papers Nos. 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27)

Problem is to show rates of overall reactions as experimentally observed can be calculated from rates of proposed elementary reactions. These overall rates vary considerably from hydrocarbon to hydrocarbon.

Knox et al (21, 22) compared rates for the propagation reaction for various hydrocarbons and found them similar. He points out that for various hydrocarbons the overall rate depends on five factors. Although these factors may not vary much from hydrocarbon to hydrocarbon, the cumulative effect causes observed differences in overall rate.

One of the major difficulties in working out generally accepted reaction schemes is the influence of wall reactions which vary with the experimental technique. Szabó (20) compared the effects of hydrofluoric acid treated and untreated Pyrex walls on rates of elementary reactions. Discussion includes further contributions to this problem.

Conflicting evidence on the point of oxygen attack seems to be resolved by the experiments of Minkoff et al (18) using deuterated propane. Oxygen attack follows the order found for other reagents. The probability of attack at primary C–H bonds is greater than at secondary bond.

The mechanism of low temperature (423–513 C) oxidation of methane was elucidated by Enikolopyan (27). Direct computations based on a simple reaction mechanism lead to a value of overall rates, activation energies and temperature dependence of the maximum intermediate concentration close to experimental values. Proof of uniqueness was not given.

Kozlov (25) measured an overall rate of oxidation of methane at high temperature (700–1100 C). Using this rate, computed burning velocities (Zeldovich-Frank-Kamenetskii-Semenov theory) agreed with measured burning velocities for lean mixtures.

Low-pressure (5–8 mm) high-temperature methane-oxygen reaction has less complicated kinetics than under other experimental conditions, according to Fabian and Bryce (26), who detected products by mass spectrographic techniques. Only CH_3, HO_2 and H_2O_2 were found.

Glick (17) reported decomposition products for methane and methane-oxygen mixtures resulting from very short reaction times (0.25–4 milliseconds) by a shock-tube technique compare favorably with equilibrium calculations based on identified species; also true for ethane and butane.

Skirrow and Tipper (24) proposed for all hydrocarbons a general mechanism of formation of CO and CO_2. Production solely from aldehydes explains relative yields for most cases reported in the literature.

Ferguson and Yokley (19) studied cool flame reactions for propane, using carbon tracers. Point of origin of product and plausible mechanisms for reaction were assigned.

E. Inhibition of Oxidation Reactions (Papers Nos. 28, 29, 30, 31)

Oxidation inhibition is related to engine knock and is caused by the effect of a trace additive on reaction chain mechanism.

Waddington (28) and Cullis and Khokhar (29) demonstrated by closed vessel studies of different systems that the mechanism of inhibition was stabilization of free radicals in the gas phase.

Rosser, Wise and Miller (30) studied effect of halogens on burning velocity of hydrocarbons. The reduction in burning velocity is attributed to the participation of the halogen-halide molecule in the flame reaction.

Although tetraethyllead has been used as an antiknock for many years, the mechanism of operation is not clear. Walsh and co-workers believe that the PbO formed operates as an antiknock in the form of a smoke. On the other hand, Norrish and co-workers deduce from flash photolysis experiments that PbO operates in the gas phase as a vapor.

Walsh and his colleagues present their arguments in Paper (31). The controversy apparently can only be settled by observations in an engine because both experiments involve conditions far removed from engine conditions.

Dorothy M. Simon, USA

3077. Kozachenko, L. S., Effect of flow pulsations on the turbulent speed of flame propagation, *ARS J.* **29,** 10, 761–764 (Russian Supplement), Oct. 1959.

The mechanism of flame propagation in a turbulent stream is considered. A burner is described in which the degree of turbulence can be varied from 1.7 to 15.7%. Measurement of the turbulent characteristics by means of a glow-discharge anemometer and a thermal anemometer has shown that the glow discharge exhibits no time delay at a pulsation rate up to 20 kc and that it can be used under laboratory conditions. An experimental estimate is made of the role of flow pulsations in the transfer of the flame through the combustible mixture. Certain results are reported on the measurement of flow pulsations behind various turbulizing devices under conditions of isothermal flow and combustion of a homogeneous fuel-air mixture. It is shown that the turbulent flame speed can be represented in the form of the sum

$$\mu t = \mu n + \mu' + \mu''$$

where μn is the normal speed of propagation of the flame, μ' the mean square pulsation of the isothermal flow and μ'' the additional pulsation generated by the flame.

From author's summary by M. F. Hoare, England

3078. Markstein, G. H., Composition traverses in curved laminar flame fronts, Seventh Symposium (International) on Combustion, London and Oxford, Aug. 28–Sept. 3, 1958; New York, Academic Press, 1959, 289–295.

The composition across a two-dimensional burner flame was measured by means of quartz sampling probes. A slot burner was used with provision for presenting air entrainment in the burned gases. Fuel rich propane-air mixtures were used. Hydrocarbon and oxidation product concentrations were plotted as a function of distance normal to the flame front. Only CO, CO_2, and H_2O were found as oxidation products. The composition profiles indicated shifts in qualitative agreement with predictions based on transport processes across flow lines. The results are compatible with the changes in burning velocity required by fluid mechanics. However, temperature measurements were inadequate because they were based on water-gas equilibrium rather than direct measurement.

J. H. Davidson, India

3079. Prudnikov, A. G., Flame turbulence, Seventh Symposium (International) on Combustion, London and Oxford, Aug. 28–Sept. 3, 1958; New York, Academic Press, 1959, 575–582.

As the inexplicably high velocities of combustion in turbulent flames had been measured, the question arose whether the combustion rate is accelerated by the self-turbulence generated during combustion. Author measured the turbulence characteristics, i.e.

mean quadratic lateral turbulence velocity, intensity of turbulence, Lagrangian scale of turbulence and turbulent diffusion coefficient in cold flows, hot flows and benzene-air flames. The measurement was carried out by an optical-diffusion method. This method is based on the following equation which represents the concentration of luminous particles introduced into a flow (tobacco smoke in cold flow, NaCl vapor in hot flow and flame): $I(x,y) = (\overline{Y^2})^{-1/2} \exp(-y^2/2\overline{Y^2})$, where $I(x,y)$ is the intensity of light at a point (x,y) on the photographic plate, $\overline{Y^2}$ the dispersion of turbulent transfer of particles.

The measurement behind 18-mm grid of flame-holders in a 100-mm tube shows that the intensity of turbulence during combustion in lean mixtures is several times less that than in cold flow (300 K), which is accounted for by a decrease in the gradients of the mean velocities during combustion. The intensity rises gradually in richer mixtures; finally it obtains 2–3 times greater value than in cold flow. Author ascribes such an increase in turbulence to an increase in self-turbulence of the flame following the rise in temperature. He concludes that the intensity and scale of turbulence in a flame, as in a cold flow, do not depend on the mean velocity behind the combustion zone. On the other hand, their values in an open flame (combustion occurs out of the tube) is always greater than that in a closed flame (combustion occurs in the tube). This difference may be caused by the fact that the combustion in the tube will accelerate the flow along the tube axis and consequently decrease the lateral scales and increase the longitudinal ones. M. Kunugi, Japan

3080. Basevich, V. Ya., and Kogarko, S. M., Structure of turbulent flame of homogeneous and heterogeneous mixtures, *ARS J.* **29,** 10, 756–761 (Russian Supplement), Oct. 1959.

The changes occurring in concentration of the initial fuel and of combustion products over the entire length of the combustion zone in a turbulent flame have been studied. Time of transformation for homogeneous mixtures is less than one milli-second and fuel/air mixture in the combustion zone has a temperature close to initial. In case of atomized fuel, disappearance of combustible follows law anticipated from consideration of evaporation rate for drops of diameter 180–100μ. However, for small drops $\leq 80\mu$ corrections have to be introduced to take into account probability of drop ignition, which may be lower for small drops as they tend to follow the turbulent pulsations more readily than do the larger drops, and therefore may not stand as great a chance of being crossed by a fluctuating combustion zone.

M. F. Hoare, England

3081. Pinns, M. L., Olson, W. T., Barnett, H. C., and Breitwieser, R., NACA research on slurry fuels, NACA Rep. 1388, 24 pp., 1958.

3082. Tower, L. K., Breitwieser, R., and Gammon, B. E., Theoretical combustion performance of several high-energy fuels for ramjet engines, NACA Rep. 1362, 18 pp., 1958.

3083. Thurlow, G. G., Similarity criteria for the study of furnace flames by means of cold models, *Combustion and Flame* **3,** 3, 373–388, Sept. 1959.

Prediction of flow patterns in industrial furnaces by observation of small isothermal models is often attempted. As a guide to such endeavors, author has developed a generalized theory of similarity between the furnace and model. The theory yields rules for flow rates, sizes and angles of fuel and air jets required for similarity. Experimental tests of the theory using a small laboratory furnace and a cold model of the same size showed agreement of flow patterns to within 20%. Reviewer believes this work to be a valuable guide to the proper use of models to simulate industrial furnaces.

A. E. Potter, Jr., USA

3084. Talantov, A. V., Estimate of operation of simplest ramjet combustion chamber, *ARS J.* **29,** 10, 769–773 (Russian Supplement), Oct. 1959.

Author continues work of Tsien ["Influence of flame front on the flow field", *J. Appl. Mech.* **18,** no. 2, 1951; AMR **4**(1951), Rev. 3985] on analysis of two-dimensional combustion chamber with uniform flow at entry, point source of ignition, flame front dividing regions of uniform mixture flow, uniform product flow. Application of energy equations, continuity and momentum yield solutions for velocity, pressure, temperature of mixture and products. Numerical solution for flame surface follows if flame speed is known and combustion time is assumed infinitesimally small. Axial distance needed for complete combustion behind flame front is then determined if actual time of combustion is known. Hence total length of combustion chamber is calculated.

Calculations give (1) permissible inlet Mach number as limited by exit choking; (2) length of flame and length of combustion zone, the latter being the greater.

Results are obviously dependent on form of assumptions for turbulent flame speed and combustion time. Paper is analytically brief. Lack of notation and diagram of flow model handicaps reader. J. H. Horlock, England

3085. Andersen, W. H., Bills, K. W., Mishuck, E., Moe, G., and Schultz, R. D., A model describing combustion of solid composite propellants containing ammonium nitrate, *Combustion and Flame* **3,** 3, 301–317, Sept. 1959.

Authors attempt to correlate the burning characteristics of heterogeneous solid rocket propellants by studying the linear pyrolysis rates of the fuel (binder) and oxidizer separately. The resulting data are correlated by the Parlin-Eyring burning rate equation, applied simultaneously to the fuel and oxidizer pyrolysis. This leads to a concept of burning defined by two surface temperatures, one for the fuel and one for the oxidizer. The two temperatures are the ones required to give the same pyrolysis rate of the fuel and oxidizer.

Reviewer believes that the assumption of equal linear pyrolysis rate of fuel and oxidizer in propellants is unrealistic in the face of the reported nonplanar nature of the burning surface. Aside from this, the paper has a wealth of interesting data from experiments, and holds promise for progress in an increasingly important field where basic understanding is conspicuously lacking.

E. W. Price, USA

3086. Graves, C. C., and Grobman, J. S., Theoretical analysis of total-pressure loss and airflow distribution for tubular turbojet combustors with constant annulus and liner cross-sectional areas, NACA Rep. 1373, 26 pp., 1958.

Prime Movers and Propulsion Devices

(See also Revs. 3052, 3082, 3084, 3103, 3120, 3133, 3136, 3137, 3138, 3141, 3142, 3152, 3153, 3155, 3207)

3087. Hara, M., and Oguri, T., Measurement of piston temperature of spark-ignition engine, *Bull. JSME* **2,** 7, 382-389, Aug. 1959.

A method is described for measuring the periodic temperature change of the piston surface of an internal combustion engine. Thermocouple wires—iron and constantan—are shorted by an aluminum metallikon film on the piston surface to form the hot junction. The alternating electromotive force of the thermocouple is applied to an R-C coupling amplifier through an input transformer. The frequency response of the hot junction is discussed in detail. However, no remark is made about the characteristic of

the amplifier including the input transformer, which is required to pass signals down to 7 cps with fidelity in the authors' experiment.
S. Kumagai, Japan

3088. Anneveld, A. S., Ship propulsion by means of free piston gasturbines, *Inter. Shipbldg. Prog.* **6,** 58, 265-291, June 1959.

3089. Sawamura, L., Application of variable area nozzle refrigeration turbine for supersonic aircraft, ASME Aviation Conf., Los Angeles, Calif., Mar. 1959. Pap. 59-AV-41, 15 pp.

3090. Kvasnikov, A. V., Estimate of internal losses in a liquid fuel jet engine chamber, *ARS J.* **29,** 10, 745-749 (Russian Supplement), Oct. 1959.

Paper describes method by which internal losses in liquid-propellant rocket engines can be estimated through comparison of calculated and measured thrust, propellant flow rate and chamber pressure and temperature.
J. V. Foa, USA

3091. Otto, E. W., and Flage, R. A., Control of combustion-chamber pressure and oxidant-fuel ratio for a regeneratively cooled hydrogen-fluorine rocket engine, NASA TN D-82, 61 pp., Nov. 1959.

From a development program at Lewis Research Center, the design of a chamber-pressure and mixture-ratio control system to increase the safety and speed of testing and to investigate the general controllability of a regeneratively cooled hydrogen-fluorine rocket engine is presented. The dynamics of the components of the system and of the complete control loop are investigated. Time-history records of combustion-chamber pressure and mixture ratio illustrating control-system performance are presented. The system proved capable of starting a hydrogen-flourine rocket engine, providing stable operation to within ±2% of the preset values of chamber pressure and mixture ratio, and limiting transient deviations in oxidant-fuel ratio sufficiently to avoid a stoichiometric mixture.
A. S. Andes, USA

3092. Useller, J. W., Effect of combustor length on afterburner combustion, *Combustion and Flame* **3,** 3, 339-346, Sept. 1959.

The effect of combustion-chamber length on afterburner combustion performance has been experimentally determined with two full-scale turbojet-engine afterburners. Combustor lengths from 2.5 to 6.5 ft have been investigated. The influence of combustor-inlet velocity, equivalence ratio, and pressure level is discussed as well as a consideration of the structural cooling requirements.
From author's summary by E. W. Price, USA

3093. Colley, R. H., Thrust reversal for jet aircraft, *J. Roy. Aero. Soc.* **63,** 586, 563-571, Oct. 1959.

3094. Sutton, G. P., Rocket propulsion systems for interplanetary flight, *J. Aero/Space Sci.* **26,** 10, 609-625, Oct. 1959.

A comparison is made of several different propulsion systems for interplanetray flight. Liquid and solid propellant rockets, propulsion systems which use nuclear energy sources, arc heating rockets, magneto-plasma devices, ion rocket propulsion, solar heating rockets, and solar sails are briefly described and their current status reviewed. Engine performance requirements for different interplanetary missions are established. These several propulsion systems are then compared on the basis of several performance criteria, environmental characteristics, vehicle requirements, reliability, current status, growth potential, and efficiency. Predictions on various propulsion system capabilities and an analysis of multiple rocket engine reliability are included. It is concluded that electrical rockets are superior for long-time interplanetary flight applications, and that chemical rockets are satisfactory for most of the immediate applications in "near" space. None of the several propulsion schemes discussed can be rejected until further technical work has been accomplished.
A. Levy, USA

3095. Pistiner, J. S., Stability criteria for the airframe dynamics of a liquid-propellant rocket, *J. Aero/Space Sci.* **26,** 10, p. 678 (Readers' Forum), Oct. 1959.

3096. Sanger-Bredt, I., The thermodynamic properties of hydrogen and water as possible working fluids for nuclear rockets, AFOSR TN 58-87 (Mitteilungen aus dem Forschungsinstitut für Phys. der Strahlantriebe E. V. 16; ASTIA AD 162 108), 58 pp., May 1958.

3097. Boden, R. H., The ion rocket engine, *SAE Trans.* **67,** 227-237, 1959.

The significant design parameters of an ion-propellant rocket engine are developed in terms of three independent parameters. These are: the ratio of the acceleration voltage to atomic or molecular weight of the propellant, gross weight of the vehicle, and thrust-to-weight ratio.

Engineering trends are presented which will lead toward advanced study of ion thrust chambers, power generation systems, and propellants.
From author's summary

3098. Brogan, T. R., Preliminary evaluation of helium as an electric arc heated propellant, *ARS J.* **29,** 9, 662-663 (Tech. Notes), Sept. 1959.

3099. Kyropoulos, P., The potential of unconventional powerplants for vehicle propulsion, *SAE Trans.* **67,** 319-325, 1959.

Magneto-fluid-dynamics

(See also Revs. 3031, 3034, 3060, 3134, 3142)

3100. Cushing, V., and Sodha, M. S., Confinement of plasma by standing electromagnetic waves, *Physics of Fluids* **2,** 5, 494-498, Sept./Oct. 1959.

In this paper the authors discuss the confinement of plasma by a one-dimensional stationary electromagnetic wave. Their analysis is similar to that carried out by former workers for a $TM_{0,1}$ mode but they have examined in detail the assumptions limiting the applicability of the present theories. One of the conditions for the applicability of the present theory is that the frequency of the electromagnetic wave should be of the same order or greater than the plasma frequency at the nodes where particle density is maximum. This condition makes the present theories nonapplicable in cases of thermonuclear interest.
From authors' summary by C. T. Chang, Sweden

3101. Ziemer, R. W., Experimental investigation in magneto-aerodynamics, *ARS J.* **29,** 9, 642-647, Sept. 1959.

A 3-inch diameter electromagnetic shock tube is studied as a means of producing the hypervelocity and ionized air flow required for magneto-aerodynamic experimental research. The electromagnetic shock tube is used to study magneto-aerodynamic interaction in the ionized flow about a blunt body. The test body is a hemispherical cylinder containing a coaxial pulsed magnet coil in the nose, which produces field strengths at the stagnation point of up to 40 kilogauss. Quantitative measurements are made of the change in the bow shock standoff distance upon application of the magnetic field. The magnetic field displaces the bow shock up-

stream and the standoff distance increases by a factor of 7.5 for the condition $(\sigma_3 B_0^2 r_b/\rho_2 U_2) = 69$. The experimental results are compared with theory, and good agreement is obtained within the range of experimental conditions.

From author's summary by J. Rabinowicz, Israel

3102. Trivelpiece, A. W., and Gould, R. W., Space charge waves in cylindrical plasma columns, *J. Appl. Phys.* **30,** 11, 1784-1793, Nov. 1959.

The propagation of electromechanical space charge waves is calculated by a quasi-static process. It is shown that these waves are essentially surface waves. Some experimental results are presented which tend to verify the calculation.

It is shown that these waves can be used to measure electron density in the plasma column. The reviewer believes that this particular application to plasma diagnostics could be quite valuable.

E. E. Covert, USA

3103. Fried, B. D., Elementary dynamics of the nonadiabatic transverse pinch, *J. Appl. Phys.* **30,** 11, 1778-1783, Nov. 1959.

The transverse pinch is similar to the longitudinal pinch in effect. The transverse pinch is generated by an induced longitudinal magnetic field that has a radial motion. The radial motion of the magnetic field causes a cylindrical shock wave to be formed which heats and compresses the plasma.

It is shown that it is possible to match the pinch rate with the power supply and geometry for maximum energy transfer. The coil which generates the field is shown to cause the matching to be practical over a wider range of variables than for the corresponding case of the longitudinal pinch.

E. E. Covert, USA

3104. Lewis, H. W., and Reitz, J. R., Thermoelectric properties of the plasma diode, *J. Appl. Phys.* **30,** 9, 1439-1445, Sept. 1959.

The gas-filled diode containing positive ions has been suggested as a device for the conversion of thermal energy into electrical energy by the mechanism of thermionic emission. The thermoelectric properties of a gas-filled diode containing a high density of positive ions is discussed here in some detail. The circuit of diode and load is considered as a thermocouple, and expressions for both Seebeck emf and thermoelectric conversion efficiency are obtained as a function of cathode and anode temperatures. The diode interior is divided into three regions: (1) the cathode sheath, (2) the main body of plasma, and (3) the anode sheath. The anode sheath is the region of large temperature gradient. The approximate temperature distribution in the sheath is found by solving a simplified thermal conduction equation. The results compare favorably with experimental data in the general literature.

J. F. Lee, USA

3105. Wright, J. K., and Black, M. C., A theory of electromagnetically driven shock waves, *J. Fluid Mech.* **6,** 2, 289-301, Aug. 1959.

A one-dimensional model of an electromagnetically driven shock wave is studied theoretically to obtain the initial current buildup and its influence on the shock formation. The example computed showed that the shock velocity did reach a final steady value, reaching 90% of this value when the total inductance of the system attained a value three times the initial inductance.

H. Yoshihara, USA

3106. Greenspan, H. P., and Carrier, G. F., The magnetohydrodynamic flow past a flat plate, *J. Fluid Mech.* **6,** 1, 77-96, July 1959.

Authors consider steady flow of incompressible viscous conducting fluid past a semi-infinite flat plate in the presence of a uniform magnetic field which is directed in the free-stream direction, parallel to the plane of the plate. Two techniques are used, one being a direct extension of the asymptotic Blasius method and the other a linearisation based on a modified Oseen approach. The skin friction, calculated by the latter technique, is found to dimish with $\beta = \mu H^2/\rho v^2$ and to drop to zero at $\beta = 1$. In fact, both techniques lead to the result that if a uniform magnetic field is applied to the flow past a semi-infinite plate, the boundary continues to thicken with increase in β until at $\beta = 1$ the entire flow is brought to rest and the induced magnetic field annuls the applied one. Referring to the Alfvèn wave speed $(\mu/\rho)^{\frac{1}{2}} H$, authors conclude that no steady subsonic flow past a flat plate can exist. This result is independent of the conductivity. Authors also consider flow past a finite plate for which both supersonic and subsonic steady flows are found to exist, but the classical results are considerably modified by the magnetic field.

D. C. Pridmore-Brown, USA

3107. Balescu, R., Irreversible processes in a plasma, *Physica* **25,** 4, 324-325 (Letter to the Editor), Apr. 1959.

Method introduced by Prigogine and author [*Physica* **25,** 4, 281-323, Apr. 1959] is used to discuss the evolution of the Liouville equation for a plasma. It is shown that the resultant asymptotic expressions may lead to collective phenomena.

D. Ter Haar, England

3108. Chu, B.-T., Thermodynamics of electrically conducting fluids, *Physics of Fluids* **2,** 5, 473-484, Sept./Oct. 1959.

The paper is directed toward a derivation of the energy equation of magnetohydrodynamics. In consideration of the equations of motion and electromagnetic theory of a moving medium, an expression for the reversible work done on a fluid per unit mass for a small change of state is calculated. Calculations were made on the basis of the nonrelativistic version of Minkowski's theory. Formula so calculated provides the basis for complete study in thermodynamics of a fluid medium under the action of electromagnetic and mechanical changes.

Formulas to be used for calculating electrocaloric effects, magnetocaloric effects, and electro- and magnetostriction effects are deduced. Finally the energy equation of magnetohydromechanics is derived. The derivation is based only on Minkowski's nonrelativistic theory and it does not presuppose the simple linear relations between the electromagnetic parameters.

R. M. Drake, Jr., USA

3109. Wu, C.-S., Simple vorticity laws in magnetohydrodynamics, AFOSR TN 58-1044 (Princeton Univ., Dept. Aero. Engng. Rep. 445; ASTIA AD 206 756), 15 pp., Nov. 1958.

In the first section of this paper author discusses the circulation-preserving motions. The discussion is based on the classical continuum theory of magnetohydrodynamics. The starting point is the equations of the classical gasdynamics with the ponderomotive force included. Author applies both the Kelvin theorem of constancy of circulation and the Bjerknes theorem. In Section II author derives the generalized Crocco's vorticity law in magnetohydrodynamics. The procedure is similar to that one used in classical gasdynamics, except that the total entropy change is split into two parts. The first part represents the entropy change due to mechanical action only and the second part indicates the entropy variation due to electromagnetic action. In connection with that the author attempts to answer two questions: first, whether the total entropy of a system may be considered as the sum of the entropy associated with mechanical and electromagnetic actions; and second, if the answer on the previous question is a positive one, may we extend similar considerations to other thermodynamic state variables? In Section III author discusses the vorticity jump across a gasdynamic discontinuity; Hayes' dy-

namic derivation of vorticity jump is generalized to the situation in question and two particular cases are discussed: steady and unsteady flows.

M. Z. v. Krzywoblocki, USA

3110. Gold, L., Asymptotic contribution to non-linear theory of plasma oscillations, *J. Electronics Control* **6,** 6, 548-549 (Research Note), June 1959.

3111. Shercliff, J. A., Magnetogasdynamics and its possible aeronautical applications, *J. Roy. Aero. Soc.* **63,** 585, 518-521, Sept. 1959.

Aeroelasticity

(See also Revs. 2694, 3005, 3059)

3112. Stearman, R., Small aspect ratio membrane flutter, AFOSR TR 59-45 (Calif. Inst. Technol., Guggenheim Aero. Lab.; ASTIA AD 209 415), 46 pp., Jan. 1959.

An experimental investigation is presented on the flutter of a small-aspect-ratio rectangular membrane in subsonic flow, the membrane being fixed at the leading and trailing edges only.

Two types of flutter were observed. The first was a small amplitude flutter, which at higher wind speed damped out. The span of the slender membrane appeared to be the unique parameter that determined and controlled the boundary of this flutter. The second type of flutter had no tendency to damp out, but became more violent as the wind speed increased.

A theoretical qualitative formulation of the two types of flutter is included in the appendix.

A. L. Petre, Roumania

3113. Cross, A. K., Generalized spectral representation in aeroelasticity, *J. Aero/Space Sci.* **26,** 11, 766-767 (Readers' Forum), Nov. 1959.

This general technique, Generalized Spectral Representation, (abbreviated GSR hereafter) is a straightforward generalization of the so-called Spectral theorem (sometimes referred to as the Schmidt-Hilbert theorem in integral-equation terminology). It is shown that GSR permits the expansion of matrices associated with various physical systems. The analytical basis and applications (with particular reference to aeroelasticity) are discussed.

From author's summary

3114. Stanisic, M. M., A remark concerning the vibration of a delta wing in supersonic flight, *J. Aero/Space Sci.* **26,** 10, 679-681 (Readers' Forum), Oct. 1959.

This paper is concerned with the formulation of an integral equation, resulting as a consequence of the boundary conditions on a delta wing by the supersonic motion in three-dimensional nonsteady flow. The method of velocity potential has been used in order to formulate this equation, which solution leads to the determination of a source function. The integral equation obtained is not solved in this paper because of the enormous difficulties imposed by its domain of integration and its unsymmetric kernel. However, the object of this paper is to show that the method of velocity potential is inconvenient for the solution of such an important problem. The Prandtl method, known as "acceleration-potential method," is much more suitable. Furthermore, this paper shows that much more remains to be learned in the theory of singular integral equations.

From author's summary

3115. Diederich, F. W., The response of an airplane to random atmospheric disturbances, NACA Rep. 1345, 36 pp., 1958.

See AMR **10**(1957), Rev. 4110.

Aeronautics

(See also Revs. 2694, 2699, 2804, 2845, 3011, 3015, 3059, 3089, 3090, 3093, 3188)

3116. Walter, W. C., Aerodynamic flight within the atmosphere: Part I, Characteristics; Part II, Limitations, *Aero/Space Engng.* **18,** 8, 43-46, 53, Aug. 1959; **18,** 9, 63-66, Sept. 1959.

A distinction is made between cruising and aerospace vehicles. The former use maximum lift/drag ratio during cruise, the latter may use higher than optimum C_1 values during re-entry of supersonic glide.

Author relates maximum lift/drag ratio, Mach number and altitude, including the effect of centrifugal forces due to the curvature of the earth, for typical hypersonic aircraft configurations.

At Mach number 4, possible C_1 optimum is restricted to a narrow range by aerodynamic heating and demands on pitch control. Wing loading for cruising vehicles can now be expressed as a function of Mach number and altitude. Structural limitations of wing loading and aerodynamic heating then define the flight regimes of cruising and aerospace vehicles.

P. F. De Neeve, Canada

3117. Barth, W., Investigations about the behaviour of airplanes when stalling (in German), *Z. Flugwiss.* **7,** 5, 120-125, May 1959.

A theory is given on the dynamically effected tip-stall of an airplane. Based on simplifying assumptions regarding the development of separation on the wing (instantaneous loss of lift coefficient if the angle of incidence exceeds the critical value), relations can be established which permit a numerical estimation regarding the tendency to stalling. The discussion is based on investigations carried out in the course of development of the airplane type Dornier Do 335 during the last years of World War II. The former German types Do 217 and Do 335 are considered.

From author's summary

3118. Wenk, F., Starting and landing of the Do 27 as measured by the Dornier research division (in German), *Z. Flugwiss.* **7,** 5, 125-131, May 1959.

In view of the present STOL requirement a short description of the Do 27 design is given. The results of some take-off and landing measurements with this type of aircraft are reviewed. Based on these results a simplified consideration of the STOL properties is given. It is used to discuss the technical possibilities of STOL aircraft development.

From author's summary

3119. Schmidt, R., Measurement of starting and landing distance (in German), *Z. Flugwiss.* **7,** 5, 131-133, May 1959.

Paper describes new equipment for accurate measuring of take-off and landing distances within a minimum of time.

From author's summary

Astronautics

(See also Revs. 2695, 2890, 2891, 3031, 3059, 3067, 3090, 3094, 3104)

Book—3120. Seifert, H. S., editor, Space technology, New York, John Wiley & Sons, Inc., 1959, xvi + 1124 pp. + appendix + index. $22.50.

Based upon a series of lectures sponsored by the University of California Engineering Extension Division early in 1958, this book has been eagerly awaited by those who had the opportunity to hear the lectures either directly, by TV or by kinescope film and by

many more who did not have such an opportunity. The volume has been well worth waiting for. It embodies within its bulky confines a comprehensive treatment of all aspects of space travel. Because of this comprehensiveness, many topics are sketchily covered in one chapter while others are treated more completely, being spread out over several chapters. However, the serious student will find enough references to further reading to enable him to go as far beyond the present book as he desires.

The 33 chapters cover such various subjects as rocket flight, trajectory optimization, orbits, lunar flight trajectories, interplanetary orbit transfer, re-entry into an atmosphere, chemical and nuclear rockets, magnetohydrodynamics, structures, design analysis, communications, guidance and physiological aspects of man in space. It isn't possible to list all of the 38 different authors; suffice it to say that all are top men in the field, well known for their contributions to rocket and missile technology. Howard Seifert has done an excellent job of editing, in that the reader finds it easy to go from one chapter to another without much difficulty, and sufficient cross references are given to facilitate the process. Yet the editor has not destroyed the authors' various styles, so one finds some chapters more lucid and informative then others.

Written for the graduate-level engineer, the language is technical and the mathematics is there, but the variety of subject matter, the numerous well-drawn sketches and graphs and the clear presentation make this the sort of book that has something for all who want to learn of the technical problems of space. It is the first high-level treatment of the entire field in one volume; each aspect of the field will hereafter require a volume of its own. We are indeed fortunate to have this excellent review of the complete field of space technology to lead the parade of the vast literature to come.

R. E. Street, USA

3121. Thomson, W. T., Orbits of artificial satellites, *J. Brit. Interplanetary Soc.* **17,** 3/4, 83-87, May/June/July/Aug. 1959.

This paper contains a review of elementary properties of theoretical orbits of earth satellites in an inverse square central force field.

C. C. Wan, USA

3122. Baker, G. A., Jr., Ford, K. W., and Porter, C. E., Optimal accuracy rocket trajectories, *J. Appl. Phys.* **30,** 12, 1925-1932, Dec. 1959.

The rocket optimization formulation of B. D. Fried has been modified by the authors by moving the reference time from burn out to final (impact), which simplifies the external functions and the boundary conditions. The effect of optimal programming versus constant thrust angle was shown to be more important for higher specific impulse and longer range, though even in extreme cases calculated the increase in range amounted only to about 0.5% (the maximum deviation from linearity was about 0.3%). However, with the expected systematic errors during the powered flight, the accuracy obtained through optimal programming is significantly greater than that of constant thrust programming.

G. S. Gedeon, USA

3123. Bellman, R., and Dreyfus, S., An application of dynamic programming to the determination of optimal satellite trajectories, *J. Brit. Interplanetary Soc.* **17,** 3/4, 78-83, May/June/July/Aug. 1959.

A thrust program for obtaining maximum horizontal speed of a missile in a uniform gravitational field is obtained by use of a functional equation technique of dynamic programming first developed by R. Bellman. A numerical solution to a specific problem is obtained, and it is noted that both thrust direction and the magnitude of the thrust are obtained simultaneously. Reviewer is not satisfied that method of R. Bellman is applicable to more general problems that are not amenable to conventional mathematical analysis, as quoted by the authors. B. D. Fried [*J. Appl. Phys.* **29,** 8, 1203-1209, Aug. 1958] has developed analytical techniques based on the Euler-Lagrange equations for the solution of general powered flight trajectory optimization problems. The results obtained by the authors is immediately deduced by use of Fried's technique. However, more complicated problems which induce formidable boundary conditions may show superiority of dynamic programming technique.

H. Lass, USA

3124. Berman, L. J., Correction of epoch error in circular orbits: Part I, Correction by tangential transfer; Part II, Correction by non-tangential transfer, AFSOR TN 59-62 (Mass. Inst. Technol., Dept. Aero. Astronautics; ASTIA AD 209 494; AD 214 637) 10 pp., Feb. 1959; iii + 36 pp., Apr. 1959.

Author has studied extensively the problem of the change of epoch. In the first part he analyzes the orbit transfers (from circular to elliptic) by means of an impulse in the same direction of the velocity (tangential transfer); this is followed in the following point of intersection by another tangential impulse which requires the satellite to retake the original circular orbit. The first part ends with two Cartesian graphs: (a) $[\Delta T/T_0;\ \Delta V/V_0]$ (period ratio; velocity ratio); (b) $[\Delta V/V_0;\ \mathrm{Tint}/T_0]$ (tint: time between two intersecting points.)

In the second part author studies the orbit transfers produced by an increment ΔV forming an angle β with the original velocity V_0. With the results obtained by analytical calculus, author is able to trace several graphs that illustrate the problem: The curves of G (gain measured in fractions of circular period) and L (loss measured in fractions of circular period) have been traced as functions of β for different values of $\Delta V/V_0$. The curves representing $[\mathrm{Tint}/T_0;\ \beta]$ for every $\Delta V/V_0$; the best maneuver curves; the influence of the central body of attraction; position of perigee, etc., all these graphs help to give the essay great practical value with sufficiently clear theory.

In every case the orbit transfers are supposed to be on the same plane.

F. R. Marsicano, Argentina

3125. Baker, R. M. L., Jr., Application of astronomical perturbation techniques to the return of space vehicles, *ARS J.* **29,** 3, 207-211, Mar. 1959.

Author argues the advantages in computing time and accuracy, of the astronomical perturbation technique, according to which a simple reference orbit that best depicts the gross motion of an object is subjected to gradual change in orbital parameters along the computed trajectory, as against the traditional direct step-by-step integration of the total effective accelerations. Despite the relative simplicity and symmetry of the equations for the traditional method the serious accumulation of end-figure errors, unavoidable in view of the inaccuracies of observation, and the large number of steps required, are shown to render the perturbation method from 11 to 165 times more accurate. The drag-perturbation equations for return of space vehicles are formulated.

A. A. Bennett, USA

3126. Miele, A., and Cappellari, J. O., Jr., Effect of drag modulation on the maximum deceleration encountered by a re-entering ballistic missile, Purdue Univ., School Aero. Engng. A-59-6, 41 pp., June 1959.

A simplified mathematical model is proposed for discussing re-entry into the atmosphere of a ballistic missile equipped with a device for controlling its drag. The analysis shows that the maximum deceleration experienced can be reduced significantly by use of any of several simple feedback control programs.

R. Kalaba, USA

3127. Eggers, A. J., Jr., Wong, T. J., and Slye, R. E., Some general considerations of the heating of satellites, *ASME Trans.* 81C (*J. Heat Transfer*), 4, 308-314, Nov. 1959.

Article presents estimates of the relative severity of various thermal environments likely to be encountered by satellites during typical maneuvers such as launch, entry into planetary atmospheres, and transit of zones of intense radiation and particle bombardment. Most attention is devoted to the entry problem, wherein the effects of lift on aerodynamic heating and maximum deceleration forces are assessed for circular, parabolic, and hyperbolic trajectories.

The heating calculations apparently consider that the gas flows are in thermodynamic equilibrium and that the radiation from the gas cap to the body is negligible. These approximations may be in error by large factors, especially for entry from hyperbolic orbits.

H. A. Stine, USA

3128. Allen, H. J., and Eggers, A. J., Jr., A study of the motion and aerodynamic heating of ballistic missiles entering the earth's atmosphere at high supersonic speeds, NACA Rep. 1381, 16 pp., 1958.

See AMR **11** (1958), Rev. 4131.

State of the art, 1959, *Astronautics* **4,** 11, Nov. 1959: (Revs. 3129–3141)

3129. Herrick, S., and Baker, R. M. L., Jr., Astrodynamics, p. 30, 180-181.

3130. Brown, L. S., Guidance and navigation, p. 33 and 150.

3131. Dorrance, W. H., Hypersonics, p. 35, 78-84.

3132. Friedman, H., Instrumentation and controls, p. 36, 114-120.

3133. Stuhlinger, E., and Seitz, R. N., Ion propulsion, p. 37, 94-101.

3134. Clauser, M. U., Magnetohydrodynamics, p. 40, 134-136.

3135. Hunter, M. W., Missile and space-vehicle design, p. 41 and 86.

3136. Wang, C. J., Nuclear propulsion, p. 42, 136-138.

3137. Zarem, A. M., Power systems, p. 44, 89-94.

3138. Ramjets, p. 46 and 171.

3139. Gerard, G., Structures and materials, p. 49 and 158.

3140. Schmidt, R. A., Test facilities and support equipment, p. 50 and 169.

3141. Wislicenus, G. F., Underwater propulsion, p. 51, 154-158.

Ballistics, Explosions

(See also Revs. 2695, 2949, 3017, 3059, 3085, 3122, 3148)

Book—3142. Chace, W. G., and Moore, H. K., edited by, Exploding wires (Based on Conference on the Exploding Wire Phenomenon, conducted by Geophysics Research Directorate, Air Force Cambridge Research Center, Boston, Mass., Apr. 2-3, 1959), New York, Plenum Press, Inc., 1959, 373 pp. $9.50.

This book presents an attempt to give an encyclopedic review of the so-called "Exploding Wire Phenomenon" (EWP): An electrical explosion of a metallic wire or a thin foil takes place when condensers of high capacity are discharged through a thin wire or foil (for example, 3-mil wire of 1 in. in length, 2 μf, 30 kv). The editors state that the mechanism of wire explosions is poorly understood. Some phases of an explosion are without any explanation, and others have been explained by a number of theories. Characteristics of EWP are: emission of light of high intensity and short duration (for example, 0.5 μsec), production of shock waves, development of metal vapor and formation of a plasma. EWP has been carried out in various gases and at reduced and elevated pressure ranges.

Applications of EWP discussed during the conference include, for example, the bonding or welding of quartz to quartz and ceramic materials to metals; the coating of metals, glass, and plastics; the study of photochemical reactions; the steepening of high power pulses; the protection of capacitor banks; the use as a light source for high-speed framing cameras; the production of cylindrical shocks; and the high-speed propulsion of space vehicles. Additional material on EWP is contained in the report for the 1958 Conference on Extremely High Temperatures (Editors: Fischer, H. and Mansur, L. W.) sponsored by the Electronics Research Directorate, Air Force Cambridge Research Center [New York, John Wiley & Sons, 1958].

Reviewer believes that EWP, which a few years ago was little known, now has reached the point where laboratory observations are translated into engineering use. EWP has entered new areas of expanding study and interest, as witnessed by the large attendance at the Boston conference.

W. M. Conn, USA

Acoustics

(See also Revs. 2811, 2822, 2823, 2859, 3022, 3183)

3143. Polyakova, A. L., Thermodynamic theory of the absorption of finite-amplitude sound in relaxing media, *Soviet Phys.—Acoustics* **5,** 1, 85-90, Aug. 1959. (Translation of *Akust. Zh., USSR* **5,** 1, 85-90, Jan./Mar. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

The article aims to determine analytically the sound absorption coefficient in continuous media. It is based on L. D. Landau's theory on the subject published in 1944 and 1954 in "Mekhanika Sploshnykh Sred" by L. D. Landau and E. M. Lifshits, pages 15, 17, 26-27, 65-67, 311, 368-370, 377-382. Author has, however, some original ideas and assumptions, although not all of them are clear and convincing.

Using Landau's methods of application of elements of tensor calculus to the theory of sound, and R. D. Fay's integral, the author obtains explicit formulas for the coefficient of absorption of sound for infinitesimal amplitude and for finite amplitude.

G. A. Tokaty, England

3144. Northwood, T. D., Grisaru, M. T., and Medcof, M. A., Absorption of sound by a strip of absorptive material in a diffuse sound field, *J. Acoust. Soc. Amer.* **31,** 5, 595-599, May 1959.

Absorption measurements on samples comparable in size to acoustic wavelength depend on sample dimensions, owing to diffraction effects. For a narrow strip of absorbing material in an otherwise reflecting plane the random incidence absorption coefficient is calculated by variational procedure. Rectangular samples are also considered in the diffraction range. Results compare favorably with experimental evidence.

F. E. Borgnis, Germany

3145. Parbrook, H. D., and Tempest, W., Sound absorption in nitrogen and oxygen (in English), *Acustica* **8,** 6, 345-350, 1958.

The published values for sound absorption in nitrogen and oxygen are examined and further values up to 44 Mc/s atm are reported. The simple hypothesis of a single time constant rotational relaxation in no way correlates the absorption and velocity measurements. From authors' summary

3146. Schreiner, J., Interferometric sound absorption measurement in carbon dioxide (in German), *Acustica* **9,** 3, 144-150, 1959.

A method of calculating absorption at 287.85 kc/s in CO_2 using the impedance interferometer with any given circuit relationships appears to afford greater precision than the usual methods. If short interferometer paths are used, it appears that the size of the transducer has small influence on the results. Measurements in the so-called interference field are hardly distorted by the diffraction and can be used for absorption measurements.

In dry CO_2 the measured coefficient $\mu = 2\,\alpha\lambda = 0.0611 \pm 0.0007$, agreeing with theory and published results.

From author's summary

3147. Papadopoulos, V. M., The diffraction and refraction of pulses, *Proc. Roy. Soc. Lond.* (*A*) **252,** 1271, 520-537, Oct. 1959.

Craggs' assumption of dynamic similarity [AMR **11**(1958), Rev. 2228] is used to solve problems of plane acoustic pulse diffraction about a reflecting or absorbing half-plane and infinite reflecting wedge. The method is then extended to the problem of a reflecting or absorbing half-plane lying in the refracting interface between two media. The method of characteristics, conformal transformation and the principle of analytic continuation are used in the different regions involved.

W. W. Soroka, USA

3148. Naugol'nykh, K. A., Propagation of spherical sound waves of finite amplitude in a viscous heat-conducting medium, *Soviet Phys.-Acoustics* **5,** 1, 79-84, Aug. 1959. (Translation of *Akust. Zh., USSR* **5,** 1, 80-85, Jan./Mar. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

The propagation of finite-amplitude spherical sound waves radiated by a pulsating sphere whose diameter is large compared to the wavelength is analyzed using the Krylov-Bogolyubov method. Author includes the effects of viscosity and heat conduction, and assumes all perturbations of the linearized equations are small. The author's quantitative examination of the second harmonic correction to the harmonic solution of the linearized equations shows that the second harmonic term increases in amplitude as the wave propagates outward from the sphere, but then reaches a maximum and is eventually damped out faster than the harmonic term. Author shows that the analysis holds only for a small-amplitude second harmonic term, but quotes additional results for a saw-tooth wave. G. E. Strickland, USA

3149. Lamb, G. L., Jr., Diffraction of a plane sound wave by a semi-infinite thin elastic plate, *J. Acoust. Soc. Amer.* **31,** 7, 929-935, July 1959.

The diffraction of a plane small amplitude sound wave incident upon a semi-infinite thin elastic plate is investigated theoretically. The problem is formulated in terms of an integral equation relating the discontinuity in pressure across the diffracting plate to its flexural displacement and the usual fourth-order thin-plate differential equation governing the flexural motion of the plate when driven by the pressure discontinuity. This pair of coupled equations is then shown to be amenable to solution by the Wiener-Hopf method. A perturbation procedure, valid in the limit of increasing plate stiffness, is employed to obtain expressions for the sound fields radiated by and transmitted through the plate as well as for the diffracted sound field.

M. Harrison, USA

3150. Mayes, W. H., Lanford, W. E., and Hubbard, H. H., Near-field and far-field noise surveys of solid-fuel rocket engines for a range of nozzle exit pressures, NASA TN D-21, 32 pp., Aug. 1959.

Results are given of an experimental investigation of the sound fields generated during static firings of rocket engines having 1500 and 5000 pounds of thrust. In the near-field survey, sample spectra are presented and a comparison is made of the noise levels generated by three 5000-pound-thrust engines having different nozzle exit conditions. An extensive survey of the 1500-pound-thrust engine is presented in the form of noise-level contours. The angular distributions of far-field noise levels and spectra are given and the overall power levels are presented on an acoustical-mechanical efficiency basis.

From authors' summary

3151. Eldred, K., Acoustical factors in jet airport design, *J. Acoust. Soc. Amer.* **31,** 5, 547-557, May 1959.

3152. Powell, A., Similarity and turbulent jet noise, *J. Acoust. Soc. Amer.* **31,** 6, 812-813 (Letters to the Editor), June 1959.

Independent derivation is noted for H. S. Ribner's [*J. Acoust. Soc. Amer.* **30,** p. 876, 1958; see also UTIA Rep. 51, AMR **12** (1959), Rev. 1583] similarity prediction that jet noise power is independent of distance in jet mixing region and falls off extremely rapidly in the downstream region. The simple similarity assumption is also shown to imply a low frequency spectrum depending on frequency squared and a high frequency spectrum depending on the reciprocal of the frequency squared. Expectations in this regard and also on the effect of jet velocity and diameter are summarized and compared with available experimental information. J. M. Robertson, USA

3153. Coles, W. D., Jet-engine exhaust noise from slot nozzles, NASA TN D-60, 30 pp., Sept. 1959.

The acoustic effects of slot nozzles having 14:1 and 100:1 width-to-height ratios were investigated using a full-scale turbojet engine. A jet-augmented flap of 3-foot chord was included in the 100:1 slot-nozzle tests. Directional distribution of sound-pressure level, frequency distribution, overall sound power, and power-spectrum-level values were obtained and are compared with circular-nozzle noise characteristics.

The changes in directional and frequency characteristics that resulted from the use of the slot nozzle were appreciable but not necessarily beneficial. Sound-pressure levels were decreased in the plane that contains the nozzle major axis and the jet centerline and were increased in the plane containing the jet centerline and the perpendicular to the nozzle major axis. The frequency distribution was generally flatter for the slot nozzle than for a circular nozzle (reductions were found at low to middle frequencies, and increases at the higher frequencies). A 3-decibel reduction in total sound power was found for the 100:1 slot nozzle. Addition of the jet flap further reduced the total sound power generated by approximately 1.5 decibels for a total of nearly 5 decibels. The largest reductions resulting from the flap occurred between 60° and 90° from the jet axis. A flap of sufficient length to shield the region aft of the 60° azimuth would be considerably longer than the useful lift-augmentation length.

An analysis of the potential noise generation of slot jets and circular jets, based on fundamental mixing-zone structure, was made. This analysis, using velocity and scale similarity relations shown to be applicable for the two kinds of jets, indicates that

the sound power generated by a long slot nozzle should be one-half that for an equivalent-area circular nozzle (3db less). The experiments showed this to be true for the 100 : 1 slot nozzle.
From author's summary

3154. Adams, H. W., Jet noise suppression, *Mech. Engng.* **81,** 8, 61-63, Aug. 1959.

3155. Fakan, J. C., and Mull, H. R., Effect of forward velocity on sound-pressure level in the near noise field of a moving jet, NASA TN D-61, 16 pp., Oct. 1959.

An in-flight investigation of the near noise field along the boundary of an aircraft-mounted jet engine was conducted over a flight Mach number range of 0.35 to 0.70 at altitudes of 10,000, 20,000, and 30,000 feet, at 2 and 3 nozzle-exit diameters downstream of the jet exit.

The sound-pressure levels were found to be constant over the full Mach number range. The results of the experiment tend to substantiate predictions of the Mach number effect on jet noise production.
From authors' summary

3156. Mayes, W. H., Some near- and far-field noise measurements for rocket engines operating at different nozzle pressure ratios, *J. Acoust. Soc. Amer.* **31,** 7, 1013-1015, July 1959.

Measurements of near- and far-field noise pressures are presented for a 1650-lb thrust engine and for 6000-7500-lb thrust engines for which the nozzle exit pressure was changed systematically in order to study its effects on the noise level and spectra. Near-field surveys indicated that the highest noise pressure occurred at about 20 exit diameters distance downstream of the nozzle near the transition from supersonic to subsonic flow. At a radial distance of three exit diameters, the noise pressure levels varied from about 145 db just upstream of the nozzle to about 170 db downstream of the nozzle, and no consistent trends were noted as a function of nozzle exit pressure. In general, the spectra at points downstream of the nozzle contained considerably more low-frequency noise than those measured upstream of the nozzle. It was noted that the maximum far-field noise was radiated in the downstream direction at angles of 30° to 45° from the jet axis. The acoustical power radiated from all nozzles averaged about 0.5% of the mechanical power of the exhaust stream, the least noise being radiated by the nozzle having an exit pressure less than atmospheric.
From author's summary

3157. Rademacher, H.-J., The sound level of vehicle noises (in German), *Acustica* **9,** 2, 93-108, 1959.

Subjective loudness measurements of heavy lorries are described and the possibility of objective estimates discussed. The loudness of such noises proves to depend, within the precision of measurements, only on sound pressure level and frequency bandwidth. There are considerable differences between the results obtained from well-known methods of loudness calculations, including the DIN method, and those derived from subjective measurements.
From author's summary

3158. Mollo-Christensen, E., Acoustical instability of jets and wakes for Mach numbers above two, *J. Aero/Space Sci.* **26,** 11, 765-766 (Readers' Forum), Nov. 1959.

Ribner and Miles have shown that a discrete interface between two moving media may be unstable to supersonic disturbances when the Mach number difference between the two media exceeds two.

This note points out that for a planar ideal jet the acoustical instability will lead to sound emission at one frequency $f = aM/4b\sqrt{M^2-4}$ and with wave fronts making an angle with the upstream direction of $\sin^{-1}(2/M)$.
From author's summary

3159. Piazza, R. S., Characteristic parameters of propagation in lined ducts (in English), *Acustica* **9,** 3, 129-134, 1959.

A method is described for the determination of characteristic parameters of sound propagation in a duct lined with absorbing material: the duct is considered as an acoustic line with distributed parameters (Sivian's monodimensional theory).

The method is applied to a circular duct with four different lining materials; the experimental values demonstrate the existence of a series resistance, which the theory does not consider. The resistance in series affects noticeably the value of the attenuation constant.
From author's summary

3160. Wood, A. B., Model experiments on sound propagation in shallow seas, *J. Acoust. Soc. Amer.* **31,** 9, 1213-1235, Sept. 1959.

3161. Hess, R. W., Herr, R. W., and Mayes, W. H., A study of the acoustic fatigue characteristics of some flat and curved aluminum panels exposed to random and discrete noise, NASA TN D-1, 41 pp., Aug. 1959.

Noise levels varied from approximately 140 to 161 decibels in these tests. Panel variables included thickness, edge conditions, curvature, and static-pressure differential. A discussion is given of siren testing as a basis for evaluating structural designs.
From authors' summary

Micromeritics

(See also Revs. 2831, 2901, 2922)

3162. Rose, H. E., A suggested equation relating to the mixing of powders and its application to the study of the performance of certain types of machine, *Trans. Inst. Chem. Engrs.* **37,** 2, 47-64, Apr. 1959.

Author proposes an expression for degree of perfection of mixing and an equation for the interpretation of the process taking place in mixing machines. The mixing and demixing in a machine are both considered. Sizes of particles, specific gravities, coefficients of friction and details of mixing machines are introduced into coefficients of the equation. The proof of the equation is based on a perfection of the curves put through the points calculated from the results of the experiments. The proof is supported by four sets of results, one of them being emphasized. An assumption, not clearly stated by research worker, is taken regarding the last-mentioned set of results. The coefficients for equation and the degree of mixing are calculated and discussed. It is an interesting attempt to obtain a general expression for the complicated process of mixing. The proof of the equation requires more support from experiments before it could be considered finalized and of practical use.
W. de O'Byrn, England

3163. Lvov, G. M., Theoretical investigation of the motion of a free body in an unsteady flow (in Russian), *Trudi Tsentr. Aerol. Observ.* no. 22, 22-31, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 340.

Equations are given for the progressive motion of a free body which is in an unsteady flow of an ideal liquid. Solutions are examined with different correlations between the density of the body and the liquid. An item is introduced, proportional to the square of the relative velocity, and the equations obtained are applied to describe the motion of a free sphere in a flow of actual liquid. The equations are solved approximately for the vertical and horizontal motions (the region is determined within which the actual solution is to be found). The general case for the motion is investigated subject to the condition that the density of the body is equal to or only slightly different from that of the liquid. In the first case an exact solution was obtained; in the second, an ap-

proximate one. An analysis of the solution shows that the sphere suspended in the liquid changes position with the flow. The character of the motion is maintained when the densities of sphere and liquid are proximate. It is also shown that the deductions obtained in the first approximation are true for the motion of the center of the mass of a body of arbitrary form.

G. A. Kolesnikov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

3164. Meskheli, K. P., An experimental study of some of the principles of motion of the bed of a stream (in Russian), *Soobshch. Akad. Nauk GruzSSR* **19,** 5, 521–528, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 402.

An investigation is made of the hydraulic modelling in relief of a sandy gritty bottom. The author introduces the following criteria for the basis of the modelling

$$R = \frac{Vd}{\nu}, \quad \frac{fx}{z}, \quad \frac{\rho_0 u^2}{(\rho_0 - \rho)\, dz}$$

$$\frac{ut}{x}, \quad \frac{(\rho_0 - \rho)}{\rho} \frac{uz}{\nu} \frac{gf}{V^2}, \quad \frac{z}{x} \frac{\nu^3}{V^2}$$

Here V is the dynamic velocity, d is the mean diameter of the particles, f is the dynamic coefficient of friction, x and z are the length and height of the sand wave, ρ_0 and ρ are the degrees of compactness of the grains of sand in the liquid, ν is the mean velocity of the flow of the stream, u is the velocity of rolling-over of the sand particles, t is the time. In addition, author states that the geometrical similarity of the gritty relief has to be secured. Investigations were carried out in a hydraulic tank of sufficient width and length, with small depths for the flow, to confirm the accuracy of the selected criteria. The values for Froude number were fairly large, which detracted some of the import of the experiments. It would have been of greater value to have carried out the investigations in a water (or air) pressure tank with a glass surface; in such a case the influence of Froude number would have been entirely neutralized. The paper also gives an example of recalculation of data for modelling, obtained in field experiments. The difficulty that, together with Reynolds criterion, the dominant influence was exercised by Froude number does not justify the use of experimental data for field work without a special analysis of the influence of Froude number on the form of the sandy layers being developed.

I. I. Levi

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

3165. Hasenclever, D., The examination of filters for the separation of radioactive aerosols (in German), *Staub* **19,** 2, 37–43, Feb. 1959.

Article describes three different methods and test arrangements for the testing of the precipitating degree of filters. They permit the observation of the behavior of filters towards aerosols, the size of which ranges from the submicroscopic range to the 10μ range. A defined quartz dust, a paraffin oil smoke, as well as radioactive indicated suspended matter < 0.3μ diameter were used as test aerosols. The results obtained from the same filter materials by different methods are compared with each other and are discussed. It is made clear that the testing of filters solely by one of the three methods can only be regarded as sufficiently precise for certain sundry cases. In particular, with the aid of measuring results it is shown that an oil smoke test alone can lead to false conclusions regarding the useability of a filter in practice. A testing by all the methods described permits a comprehensive and practical judgment about the useability of a filter for the precipitation of radioactive aerosols.

From author's summary

3166. Effenberger, E., Comparative measurements with different dust measurement procedures (in German), *Staub* **19,** 2, 44–46, Feb. 1959.

Over a period of twelve months it was possible to carry through comparative measurments with the Diem adhesion foil method, the Löbner dust-collection apparatus and the Effenberger registering appliance. Between the results given by the registering method and those given by the adhesion foil method there exists a statistically secured connection, if the average of the measuring results of at least five adhesion foils is taken as a basis. It was not possible to establish any statistically secured connections between the results obtained from the collection apparatus and the adhesion foils on the one hand and the collection apparatus and the registering appliance on the other hand.

From author's summary

3167. Walkenhorst, W., Aerosol filtration with membrane filters for particles below 0.1 microns (in German), *Staub* **19,** 3, 69–72, Mar. 1959.

Tests are carried through to establish the filter capability of membrane filters, for which a fine particle aerosol with particle sizes up to about 0.1μ was used. Article describes the test arrangement including the aerosol source used. The results obtained with German membrane filters for two different permeability stages—coarse and middling—are quoted. With 0.1μ particle size the filter capability is nearly 100%, growing somewhat less with decreasing particle size. But with particle sizes of 0.01μ and the filter for the coarse permeability stage, the filter capability still comes to about 94%, and the filter for the middling permeability stage to 97%. A minimum of precipitation, similar to the results found by Fitzgerald and Detwiler, could not be established. Even with two control measurings made with a filter of American origin, it was not possible to determine this minimum with certainty.

From author's summary

3168. Roeber, R., Photometric evaluation of fine dust samples (in German), *Staub* **19,** 3, 73–78, Mar. 1959.

The demand for a speedy and objective method for the evaluation of dust preparations such as are supplied by conimeters and thermal precipitators leads to photometry. The article defines physically a "photometric dust concentration" and compares this with a "particle concentration." Then the author investigates in how far it is possible to obtain the newly defined measurement value experimentally and especially with conimeters. Going by research results hitherto obtained this appears approximately possible. By applying a few standardizing measures it is possible to assure the reproductivity of the measurement value for a certain photometric concentration measurement value, which—sufficing for the practice of measuring extremely fine dusts—can be regarded as independent of the measuring method and the measuring appliance.

From author's summary

3169. Olaf, J., Measurement of dust (in German), *Staub* **19,** 6, 221–226, June 1959.

Article provides a survey of the dust-measuring processes and methods mentioned in literature, special consideration being given to the problems arising in the coal mining industry. Special care has been taken to include those measuring instruments, appliances and processes which are as yet little known.

From author's summary

3170. Reif, E., A procedure for the determination of dust concentration in dust chambers (in German), *Staub* **19,** 6, 227–228, June 1959.

Article describes a simple method permitting the measurement of the concentration in dust deposits obtained by the Midget-Scrubber D 21 by Dautrebande, with the aid of the light dispersion measurement in the Leitz compensating photometer. The method

has not been devised to measure dusts underground. It is particularly suitable for the time-saving control of the concentration, especially of quartz in dusting chambers.

From author's summary

3171. Winkel, A., A new method for the measurement of dust (in German), *Staub* **19,** 7, 253–255, July 1959.

Article reports on a new dust-measuring method with soluble Microsorban-Filters. Compared with hitherto customary methods, this measuring method has a great advantage inasmuch as it permits the precipitation of large quantities of dust without any material pressure rise on the filters and makes them easily accessible for an analysis. From author's summary

3172. Schmidt, K. G., and Heidermanns, G., Investigation of dust samples with the phase contrast microscope, especially when using membrane filters (in German), *Staub* **19,** 12, 413–416, Dec. 1959.

Article describes a process for the phase contrast microscopic quantitative mineralogical determination of dust types on membrane filters. In this process the dusts are evaluated without modification of their aggregate condition. The necessary numerical tables are given. From authors' summary

3173. Schmitt, K., Basic experiments with the thermal precipitator (in German), *Staub* **19,** 12, 416–421, Dec. 1959.

Article discusses the examination of particles of aerosols in a suspension condenser with temperature gradient. The movement of the particles in the temperature field can only be described where and when they are large or small against the free path length of the gas. The corresponding formulas are quoted. The results obtained are applied to the thermal precipitator.

From author's summary

3174. Friedrich, W., Particle size analysis with the sedimentation balance (in German), *Staub* **19,** 8, 281–287, Aug. 1959.

Article discusses the physical processes and principles of a sedimentation analysis. Author distinguishes between differential and integral processes with pipette appliances and sedimentation balance system Oden-Bachmann. The operation and the evaluation with the balance are discussed in detail, also the influences of the actual test.

Analytical results show, by the particle size characteristic curves of quartz powder, a conformity with the Andreasen apparatus and balance and give the limits of the integral process, dependent on the commercial Sartorius apparatus. A large vertical cylinder charged sufficiently is proposed. The process of author for sifting and sedimentation was also extended to the Sartorius balance. From author's summary

3175. Effenberger, E., Investigations about the measurement accuracy of dust settlement experiments with adhesive foil (in German), *Staub* **19,** 9, 313–319, Sept. 1959.

For a period of one year the collection of dust was measured with adhesive foil at fifteen points arranged in three longitudinal rows on the flat part of a roof. The results showed statistically secured differences between the points of measurement. It was found that the precipitation was somewhat greater on the two outer rows than on the middle row. Although these differences are not statistically secured, they can nevertheless be regarded as an effect of turbulence at the edges of the roof. Beyond this, the test showed that at least five foils should be laid out to determine adequately the dust precipitation at any one point or place. When measuring the dust precipitation on a larger area, however, it is not necessary under certain circumstances to cover a measuring point with several foils, provided the surveyed area is sufficiently closely consolidated. The decision can be made with the help of statistical planning. From author's summary

3176. Hartmann, W. L., Investigations on the comparability of various dust measurement methods (in German), *Staub* **19,** 10, 345–351, Oct. 1959.

Results of various dust-measuring methods were compared. The investigations proved that there exists a good degree of correlation between the results of the various methods in the case of dusts with a small portion of agglomerations. With dusts having a large share of agglomerations, it is necessary to determine the conversion factors between the measuring methods in each case and they apply only for the dust condition concerned.

From author's summary

3177. Remmers, K., and Bingel, R., The importance of the gas distribution in electro filters (in German), *Staub* **19,** 12, 422–424, Dec. 1959.

Different air velocities in the filter ducts invariably result in separation losses. Two methods are indicated by which the loss can be determined when the velocity differences are known, for instance through small-scale model tests. In three-dimensional filter models the differences are measured with straight and right-angle gas feed. For a filter with straight gas feed the separation loss is represented as a function of the number of gas distributor plates. From authors' summary

3178. Whiteley, A. B., and Reed, L. E., The effect of probe shape on the accuracy of sampling flue gases for dust content, *J. Inst. Fuel* **32,** 222, 316–320, July 1959.

Tests have been carried out in order to develop probes for dust sampling that would be more robust and compact than those normally employed. Several probes of different shapes were tested and, of these, two "non-standard" types were considered sufficiently promising to warrant further investigation. These were tested over a wide range of sampling velocities using a relatively coarse test dust and their performance was compared with that of the "standard probe" under comparable conditions. It was found in all cases that the weight of dust collected by the probes was almost independent of the sampling rate.

From authors' summary

Porous Media

(See also Revs. 2830, 2906, 2909)

3179. Lebedev, S. A., Usenko, V. F., and Shvidler, M. I., On filtration of flow passing from single phase to two-phase state (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 7, 56–60, July 1958.

The oil well interference is discussed for a layer in which the pressure is higher than the saturation in certain regions and lower in others.

Using S. A. Khristianovich's function, the problem is reduced to the determination of a function which is harmonic within the whole flow region, except the singular points corresponding to the wells. The solution is looked for under the form of a sum of two harmonic functions having the same singularities. The first function corresponds to a single-phase flow throughout the whole region while the second represents the effect of the decrease of pressure below that of saturation for certain wells. Further, a procedure is given for determining the dependence of Khristianovich's function on pressure by using the pressure-rate of flow curve of the well. An example of application is included. Possibilities are also discussed for extending the method to the case in which the liquid compressibility in a single-phase flow is taken into account.

T. D. Oroveanu, Roumania

3180. Paria, G., Deformation of porous transversely isotropic elastic material containing a fluid, *Bull. Calcutta Math. Soc.* **50,** 4, 169–179, Dec. 1958.

Extending Biot's treatment of the consolidation of porous elastic medium, derivation of solution for the three-dimensional deformation of such body is discussed with the aid of two different stress functions. The stress distribution in a semi-infinite body is treated as an illustration. T. Mogami, Japan

3181. Rao, J. V., An analytical approach for testing the stability of slopes subjected to efflux of seepage (in English), *J. Sci. Engng. Res., India* **2,** 2, 161–174, July 1958.

Geophysics, Hydrology, Oceanography, Meteorology

(See also Revs. 2692, 2704, 2811, 2826, 2830, 2948, 2984, 2996, 3000, 3017, 3160, 3194, 3196)

3182. Desbrandes, R., Reverdy, X., and Lagarde, A., Contribution to the study of the velocity of seismic waves (in French), *Rev. Inst. Fr. Petrole et Ann. Comb. Liquid* **14,** 4/5, 535–548, Apr./May 1959.

Article describes measurements of the longitudinal and transverse wave velocity of rock specimens about 10 cms long. The apparatus used was a piezo-electric transducer developed by the French Petroleum Institute. Owing to the limitations of instrumentation, it can not be relied on to give accurate measurements of velocities less than 2500 meters/sec. This limits the usefulness of the method, as many wave velocities (especially transverse) fall below this limit.

The pulse given by the generator is resolved in terms of a Fourier integral and calculations are given of the expected frequency response.

Measurements were made on a variety of rocks and Poisson's ratio was correlated with porosity in the case of a series of sandstones. J. M. Jackson, Scotland

3183. Koltonski, W., and Malecki, I., Ultrasonic method for the exploration of the properties and structure of mineral layers (in English), *Acustica* **8,** 5, 307–314, 1958.

The method developed by the authors is based on the same principle as hydrolocation and ultrasonic flaw detection of metals using frequencies from 50 to 300 kc/s. The attenuation and velocity of wave as well as the location of the eventual inhomogeneities of the medium are determined on the basis of the size, shape and time of passing of the direct or reflected pulse. The experimental material, collected in the salt mines and quarries, proves that the conditions of ultrasonic propagation in rocks are exceedingly more complicated and subject to changes than in metals or water, but the range and accuracy of discernment is quite sufficient for practical aims. The measurements embrace the damping and velocity of ultrasonic waves in different rocky media. Various tests have also been carried out on detecting different types of inhomogeneities in layers of salt and rocks. General relations between parameters of ultrasonic propagation in those media and their structure, physico-chemical properties and types of discontuities are determined.

From authors' summary

3184. Pires Castanho, J., Experimental research on the formation of spits along coasts (in Portuguese), Minis. Obras Publicas, Lab. Engen. Civ., Lisboa, Mem. 139, 6 pp., 1958.

Article describes how spits are formed and develop on laboratory models, analyzing factors appearing to have a fundamental bearing on their characteristics. It goes on to examine the effect of solid discharge and the wave characteristics on the direction assumed by a spit. From author's summary

3185. Harbeck, G. E., Jr., Evaporation suppression in laboratory and field, Proceedings, Seventh Hydraulics Conference, Iowa Institute of Hydraulic Research, June 16-18, 1958; Iowa City, Iowa, State Univ. of Iowa, 1959, 43-51.

Author reviews the results of laboratory and field tests to measure suppression of evaporation from reservoirs by placing a monomolecular layer of hexadecanol or octadecanol on the surface. Tests are described in twelve-inch jars, ten-foot diameter tanks and lakes of several acres. Effectiveness of retardation of evaporation varied widely, depending on circumstances, but was considered sufficient to warrant further study. No harmful effects on water quality have been noted, either for subsequent use by humans or on biological balance in the reservoir during treatment. If present problems could be solved, the water economy of arid regions would be greatly benefited.

H. McKee, USA

3186. Gleeson, T. A., Observational probabilities and uncertainty relations for meteorology, *J. Meteorol.* **16,** 2, 149–154, Apr. 1959.

Relations have been derived to give the probability of observing one or more specific atmospheric features, and the uncertainties of position, speed, and gradient once such features are detected. Suggested uses of these relations include network design, estimation of climatological frequencies, and evaluation of observational barriers to the development of meteorology as an exact science.

From author's summary by J. C. Geyer, USA

3187. Yamamoto, G., Estimation of additional downward radiation from aerosols over large cities, *J. Meteorol. Soc. Japan,* 75th Anniversary Volume, Nov. 1957; 1–4.

Using Yamamoto radiation chart and estimates of amount of particulate matter in air over Osaka, Japan, author concludes that downward infra-red radiation from aerosols is not important in heating lower atmosphere over large cities. Author speculates on causes of warmer temperatures in cities as opposed to surrounding countryside since radiation deficit in city would lead to the opposite result. He believes that burning of fuels might be sufficient to account for extra heat, but diminution of evaporation in cities is of equal importance; the difference in radiative surface conditions and presence of city fog is also important.

W. P. Elliott, USA

3188. Ackermann, P., Correction of the formulas for computation of heights in aerological soundings and temperature gradients of a heavy gas (in German), *Meteor. Rdsch.* **11,** 4, 120–122, July/Aug. 1958.

Author uses curvature of earth, statistical mechanics, and ergodic theory to correct hydrostatic equation and adiabatic lapse rate formula. Owing to an elementary error, not original with author but for which no reference is given, all new results are wrong.

Error (author's Eq. [3]), which has been too often repeated, consists in failure to realize that pressure is a surface force defined at a point, and that the associated volume force is a gradient vector, also a point function rigorously derived from the surface force by Gauss' theorem.

M. G. Wurtele, USA

Naval Architecture and Marine Engineering

(See also Revs. 2687, 2917, 3088)

3189. Landweber, L., and Macagno, Matilde, Added mass of a three-parameter family of two-dimensional forms oscillating in a free surface, *J. Ship Res.* **2**, 4, 36–48, Mar. 1959.

The added-mass characteristics of two-dimensional, symmetrical, shiplike forms oscillating either vertically or horizontally are derived mathematically for a three-parameter family of sections, generalizing authors' earlier treatment [AMR **11** (1958), Rev. 3851] of a two-parameter family of ship sections known as the Lewis forms. In addition to the draft-beam ratio and the section-area coefficient, the ratio of the radius of gyration about the transverse axis in the free surface to the draft is used as a significant parameter. The physically useful ranges of variation of the parameters are determined, and 70 typical sections or profiles are plotted for various possible combinations of values of the parameters. Analytical expressions for the added-mass coefficients for vertical and for horizontal oscillations are obtained and presented in a series of curves as functions of the above three parameters. Authors suggest that the added-mass coefficients of arbitrary shiplike sections may be obtained, with only small error, from these curves by interpolation at the parametric values of the given section. An approximate expression is derived for computing the added-mass coefficient for horizontal oscillations from a knowledge of the coefficient for the Lewis forms, being given the values of the three parameters.

R. Heller, USA

3190. Weinblum, G., Brooks, S., and Golovato, P., Experimental investigation of the inertia and damping coefficients of a spheroid and surface ship in free heave, *Inter. Shipbldg. Prog.* **6**, 54, 45–62, Feb. 1959.

Investigation is made at the David Taylor Model Basin of the damping and added mass coefficients of a 7 to 1 prolate spheroid subjected to small free-heaving oscillations near the surface. Tests were performed at various depths from surfaced to deep submergence, over a range of Froude numbers, and for a limited frequency range. Similar tests were performed for a model of a surfaced aircraft carrier of 0.6 prismatic at several displacements.

A detailed evaluation is made of previous work in the field of near-surface oscillations. Although of limited frequency range, the results of the present tests show reasonable agreement with available theoretical results. Tests for surface ship models using forced-oscillation techniques have been performed recently by the third author.

From authors' summary

3191. Shmyrev, A. N., A. N. Krylov's contribution to the knowledge of the stabilization of ships (in Russian), *Trudi Nauchno-Tekhn. o-va Sudostroit. Promsti* **7**, 2, 21–32, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 368.

The enormous role filled by A. N. Krylov in the development of knowledge of methods for general and local stabilization of ships receives mention. An evaluation is given of a series of studies by Krylov dealing not only with the theory of damping devices to eliminate rolling in ships (gyroscopic dampers, damping cisterns—passive and active) but also with the theory of the stabilization of various devices and measuring apparatus distributed in the ship (local stabilization). It is shown how the scientific ideas of Krylov for developments and extensions in the field of the theory of active damping tanks, lateral stabilizing fins and gyroscopic (local) stabilizers will endure.

V. S. Voitsenya

Courtesy, Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

3192. Firsov, G. A., The action of Fram's damping tanks in irregular sea disturbance (in Russian), *Trudi Nauchno-Tekhn. o-va Sudostroit. Prom-sti* **7**, 2, 119–131, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 369.

Author applies the theory of random processes for the calculation of the statistical characteristics of the pitch and roll of a ship fitted with Fram's passive stabiliser-cisterns. So far in the theory of Fram's cisterns, investigations have been restricted to the rolling of a ship in a regular sea swell. An experimental verification of the efficiency of these cisterns gave contradictory data, indicating the necessity for further work on the theory of Fram's cisterns. Author assumes that the ordinate of the wave profile at the place occupied by the vessel $\zeta(t)$ is a stationary random magnitude. Formulas are given for the dispersion of the wave ordinates $D\zeta$ and the spectral density $S\zeta(\omega)$, which can be calculated at a known intensivity of the waves' disturbance. As the result of the solution of a system of differential equations for the roll of the ship fitted with cisterns the so-called transmission functions of the ship $\Phi_i(\omega)$ are found, which characterize the ability of the ship to transform into energy the components of a sea-wave motion with a frequency of ω. The dispersion of the angle of roll and the relative transposition of level in the cisterns D_{x1} and D_{x2} are found by means of the functions $\Phi_i(\omega)$ and $S\zeta(\omega)$. This enables all the statistical characteristics of the heaving of a ship to be determined, and from them to derive equations for finding the optimum values for the frequencies of the natural vibrations and the coefficient of damping for the stabilizing fluid. The results obtained were used for the evaluation of the efficiency of Fram cisterns during their tests on the steamer "Meteor" by A. N. Krylov in 1913. From the curves published it is evident that the cisterns decrease the heaving provided the maximum curve of distribution of the energy of wave-disturbance by frequencies lies close to the frequencies of the free rolling of the ship in calm water. In the opposite case the cisterns may actually intensify the rolling of the ship. It is shown that with a selection of cisterns of the correct dimensions (with the aid of the calculations for the heaving of the ship due to irregular wave motion) they can be successfully used, more especially in ships travelling in ice-encumbered waters. It is also noted that the theory of random processes can be used for other problems, for instance when computing the general and local strength of vessels.

V. S. Voitsenya

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

3193. Voevodin, N. F., Influence of taking on a load on the dynamic stability of a ship (in Russian), *Trudi Nauchno-Tekhn. o-va Sudostroit. Promsti* **7**, 2, 149–160, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 370.

The problem is solved theoretically on the change in the dynamic stability of a ship when taking on a small load and on the position of the boundary level. Subsequently the solution is extended to cover the cases of loads of finite weights and loads of a liquid and of a friable nature.

G. E. Pavlenko

Courtesy, Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

3194. Saltovskaya, V., The effect of waves on the stability of ships (in Russian), *Morsk. Flot.* no. 3, 5–7, 1958; *Ref. Zh. Mekh.* no. 1, 1959, Ref. 371.

Taking cognizance of the fact that the dimensions of a ship are commensurable with the dimensions of a wave, author calculates the characteristics of stability for different positions of the ship in relation to the wave. It was seen that these characteristics can, in various circumstances, differ considerably from each other. Thus, for instance, the transverse height of the ship, finding itself in the trough of the wave, can exceed by 1½ times the

metacentric height of the ship, finding itself on the crest of the wave. Disregard of this difficulty may lead to disaster, especially in those cases where the velocity of the oncoming wave is close to that of the wave.

N. N. Moiseev

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

3195. Khalevin, A., The standardization of the stability of sea-going ships (in Russian), . *rsk. Flot.* no. 10, 20–22, 1956; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 372.

The shortcomings of present-day standards are noted in regard to the stability of civil, marine and coastal ships and proposals are put forward which deal principally with methods of computation for openings in the hull, for superstructures and, in connection with these items, improvements in relation to the size of the angle of flooding.

G. E. Pavlenko

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

3196. Fedyaevskii, K. K., and Fireov, G. A., Heeling of a ship due to wind action (in Russian), *Sudostroenie* no. 12, 3–11, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 374.

An approximate method of calculation is given for the heeling of a ship under the action of wind. This is based on the experimental study of hydro- and aerodynamic forces acting on a ship. It is assumed that, during the whole period of time from the beginning of the wind's action up to the moment of the ship's attaining the maximum angle of heeling over, the velocity, the ship's course and the angle for the draught remain unchanged. The duration of the wind's action is taken to be in excess of half the period of the roll of the ship in smooth water. Equations are derived for the dynamic equilibrium determining the motion of the ship under the wind's action. Further, the relation is established between the magnitude of the forces and the moments of the forces which take part in the equations, and the elements of motion of the ship and time. The integration of the equations is carried out piecemeal, corresponding to the division of the whole process of the motion of the ship into two periods: impact (of very small duration) and post-impact, characterized by the constancy of the magnitude and direction of the vector of the relative velocity of the air. The calculations are supplemented by curves and directions which make it easy to evaluate the anticipated size of the heel at given parameters for the wind.

A. A. Kostyukov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

3197. Khaskind, M. D., Some features of rolling and its quietening (in Russian), *Trudi Nauchno-Tekhn. o-va Sudostroit. Prom-sti* **7**, 2, 61–71, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 376.

Solutions are studied of the nonlinear problem on the determination of the amplitude of the rolling of a ship in smooth water and on wave action both when the ship is in motion and at a standstill. The possibility is indicated of studying the differential equation for the nonlinear oscillations of the ship independently from the solution of the hydrodynamic problem. When investigating the roll of a ship caused by wave action when the ship is not under way, indications are given of the variable character of the influence of nonlinearity with variable behavior of the amplitude of the disturbing moment $B_\sigma(\sigma_0)$, where σ_0 is the frequency of the oncoming waves. In particular, if function $B_\sigma(\sigma_0)$ decreases regularly, then the nonlinear effects are insignificant. When the ship is moving through rough seas this is taken into account as wave damping and as vortex damping, and it is shown that for moderate ship speeds the nonlinear effects can be disregarded. The question of the roll of a ship fitted with bilge keels is studied. The case is also examined of the automatic reduction of roll by the use of stabilizing fins. For this case a method is given which provides a full solution of the problem.

V. S. Voitsenya

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

3198. Boericke, H., Jr., Unusual displacement hull forms for higher speeds, *Inter. Shipbldg. Prog.* **6**, 58, 249–264, June 1959.

A sharp increase in the wave resistance has limited speeds of full-bodied surface vessels to a practical maximum which has sometimes been called the "wave barrier." Two approaches toward increasing the top speed of displacement-type surface ships are investigated. The first approach is that of keeping Froude number constant and increasing length. The second approach, involving operation at high Froude numbers, is emphasized. This involves a study of minimum wave resistance at Froude numbers greater than 0.35. Principles for minimizing wave resistance are proposed. The wave resistance of certain elementary shapes is reviewed, and several forms likely to have a minimum wave resistance are discussed with reference to the principles proposed, and with reference to operation in rough seas. Heavy displacement-type hull forms exist which "break the wave barrier" reaching Froude numbers greater than 0.9 (speed-length ratios greater than 3.0), thus multiplying their speed capabilities. The form characteristics which make for a higher speed may, within limits, also make for a maximum propulsive efficiency and a minimum motion in a seaway. The concept of increasing depth instead of increasing length in order to increase speed and seaworthiness is also briefly investigated.

From author's summary

3199. Shuford, C. L., Jr., A theoretical and experimental study of planing surfaces including effects of cross section and plan form, NACA Rep. 1355, 46 pp., 1958.

See AMR **10**(1957), Rev. 2966.

3200. Vaughan, V. L., Jr., The hydrodynamic characteristics of a submerged lifting surface having a shape suitable for hydro-ski application, NASA TN D–51, 39 pp., Oct. 1959.

An aspect-ratio-0.25 hydro-ski model was investigated to determine the lift, drag, and pitching moment about the trailing edge at depths of submersion of 1.0, 1.5, 3.0, and 6.0 inches over a range of angles of attack from -2° to 20° and at speeds up to approximately 85 feet per second. Comparisons between the data from this investigation and data on a rectangular modified flat plate having the same aspect ratio are presented. Discussions and comparisons of cavitation and ventilation are presented in some detail.

From author's summary

3201. Kafali, K., Investigation of the characteristics of single screw propellers with twin rudders placed symmetrically in the propeller race, *Inter. Shipbldg. Prog.* **6**, 59, 305–310, July 1959.

This work is mainly concerned with experiments made with single-screw propellers and twin rudders located in the propeller race. Only the case of rudders which were placed just behind the propeller with zero angle of attack is included.

The experiments have shown the possibility of obtaining an appreciable improvement in the efficiency and also in the thrust of the propeller for some range of rudder locations.

From author's summary

3202. Cahn, R. D., A study of the hydrodynamic loads on a cylindrical mast and radome, David W. Taylor Mod. Basin Rep. 1239, 15 pp., May 1958.

Friction, Lubrication and Wear

(See also Revs. 2672, 2721)

3203. Fein, R. S., Rowe, C. N., and Kreuz, K. L., Transition temperatures in sliding systems, *ASLE Trans.* **2**, 1, 50–57, Apr. 1959.

A pin-on-disk type of apparatus is used to study the effect of operating variables on transition temperatures with dilute solutions of pure fatty acids in pure paraffinic hydrocarbons and with a straight paraffinic mineral oil. It is found that the temperature at which the sudden transition from low to high friction and wear occurs increases with sliding speed, decreases with load, and is otherwise independent of operating variables. Empirically, the reciprocal of the absolute transition temperature varies linearly with logarithm of the ratio of load to speed. The absence of conventional hydrodynamic lubrication in this system is demonstrated.

Authors conclude that these results are inconsistent with the widely accepted concept that boundary lubricants must form a solid absorbed film to be effective. They think that it appears necessary to adopt a modified view of the role of boundary lubricant, in which rheological and other diverse physical characteristics must be considered, and not simply the state of matter in which it exists. They also think that it appears necessary to consider the interrelated kinetics of boundary film formation and welding between asperities.

It is salutary to have these points emphasized, but these findings are not so much at variance with the findings of earlier workers as might appear at first glance. Langmuir in 1920 [I. Langmuir, *Trans. Faraday Soc.* **15**, p. 62, 1920] showed that a single molecular layer of fatty acid reduces friction for a single run to the same value as that observed with excess of fatty acid. However, later work [I. Langmuir, *J. Franklin Inst.* **218**, p. 143, 1934; Bowden, F. P., and Tabor, D., "Friction and lubrication," chapter 9, London, Methuen, 1956; Hirst, W., Kerridge, M., and Lancaster, J. K., *Proc. Roy. Soc.* (*A*) **212**, p. 516, 1952; Greenhill, E. B., *Trans. Faraday Soc.* **45**, p. 631, 1949] has shown that thicker films are required to protect the substrates for repeated runs. Moreover, the adsorbed boundary lubricating films form quite slowly, particularly on freshly exposed unoxidized metal [Bowden, F. P., and Tabor, D., "Friction and lubrication," Chapter 9, London, Methuen, 1956; Tingle, E. D., *Nature* **160**, p. 710, 1947; Tingle, E. D., *Trans. Faraday Soc.* **46**, p. 93, 1950]. Clean metal surfaces brought into contact adhere [Bowden, F. P., and Tabor, D., "Friction and lubrication," chapter 3, London, Methuen, 1956; Anderson, O. L., *Bell Lab. Record* **35**, 441–445, 1957]. Locked elastic stresses may tend to peel such welds. Tangential shear strains, the passage of time, or the application of higher temperatures can reduce the peeling stresses and increase the adhesion [Anderson, O. L., *Bell Lab. Record* **35**, 441–445, 1957; Mason, W. P., *ASLE Trans.* **2**, 1, 39–49, 1959].

Boundary lubrication can only be investigated at speeds very much lower than those that will give complete hydrodynamic lubrication. There is quite a wide intermediate range of partially hydrodynamic lubrication. Authors have shown that the findings of other workers relative to boundary lubrication do not apply to all of their own results, particularly in that they found a "marked dependence of the transition temperature on both load and speed... Increasing load lowered the transition temperature while increasing speed raised it. In general, the transitions were reversible..." Now Kenyon [Bowden, F. P., and Tabor, D., "The friction and lubrication of solids," Oxford, Clarendon Press, 1954, p. 296] showed that one could get hydrodynamic lubrication with a 1-mm diameter pin at speeds as low as 20 cms/sec. Lewicki [*Engineering* **169**, p. 685, 1955; *Engineer, Lond.* **200**, p. 176, 1955; *Engineer, Lond.* **200**, p. 212, 1955] makes a cogent case for the incidence of hydrodynamic lubrication at much lower speeds still. The general picture of the load at slow speeds being supported by small areas with a local pressure equal to the flow pressure of the substrate is valid. Conditions which lead to partial hydrodynamic lubrication are conditions on a microscale and not on a macroscale and are more likely to be determined by the load and by the real area of contact than by the average pressure. It thus seems to the reviewer that the results of the present authors are explainable if one makes the reasonable assumption that the transition temperatures measured at very low speeds relate mostly to the properties of the substrates and the absorbed monomolecular and multimolecular layers; and that at higher sliding speeds, the results are influenced by the kinetics of the adsorption processes and also by the incidence of partial hydrodynamic lubrication. J. S. Courtney-Pratt, USA

3204. Hanson, S., Jones, W., and Stephenson, A., Research program on high vacuum friction, AFOSR TR 59-97 (Litton Industries of Calif., Space Research Laboratories Final Rep. 2907), 148 pp., Mar. 1959.

A twelve-month program directed towards the study of surface friction under conditions of high vacuum (10^{-8} to 10^{-6} mm Hg) has been carried out in two phases, each of approximately six months duration. The first phase dealt primarily with preparations necessary to carry out the experimental effort. The second phase was devoted to the methodical examination of the friction characteristics of a large group of materials. The principal test condition studied was that of the linear motion between two dry, clean, unlubricated, flat surfaces.

In addition to the measurement program, effort was devoted to the study of the microscopic nature of the actual surface-to-surface contacts. Examination of the results of a single sliding contact between two clean, machined surfaces led to the conclusion that each individual contact area was largely point-to-plane. Subsequent point-to-plane studies produced some extremely interesting results. It was found that models could be loaded to yield pressures, and under certain conditions could be made to slide with abnormally low friction forces and without microscopic evidence of wear or surface distortion. This work indicated the existence of two modes of contact, one of pure sliding and a second of areas undergoing shear. The low-friction, low-wear examples appear to be special cases wherein almost all contact areas are of the first type. A theory of friction has been postulated, based principally on the analysis of these tests.

During the friction experiments, various trends of the results stimulated consideration of related phenomena and their relationship to the general problem. Several miscellaneous studies were undertaken during the program, and these are also reported where significant. From authors' summary

3205. Engstrand, G., Does compensation of thermoelectric currents influence cutting tool wear, Trans. Roy. Inst. Tech., Stockholm, no. 144 (Mech. Engng. 5), 11 pp., 1959.

In machining with cemented-carbide tools the oxidation phenomenon is a contributive cause to the wear of the cutting edge. An account is given of the influence of compensating thermocurrents on the wear process. From author's summary

3206. Elrod, H. G., A derivation of the basic equations for hydrodynamic lubrication with a fluid having constant properties, *Quart. Appl. Math.* **17**, 4, 349–359, Jan. 1960.

Paper is mainly of analytical interest. Extending an idea of G. H. Wannier [AMR **4**(1951), Rev. 1416] author shows that the Reynolds equation for journal bearings (and also more refined approximations) can be obtained rigorously from the Navier-Stokes equations through a small parameter technique, the parameter being the ratio of clearance over a typical dimension of the bearing [similar developments are used by reviewer in a paper under press in *Riv. Mat. Univ., Parma*].

From the point of view of the engineer it is interesting to note that only the curvature, and not the inertia, of the film has an influence in the approximation of second order. This result seems to reduce the significance of the corrections proposed by Osterle, Saibel and others for the classical formulas giving the pressure distribution in a bearing [see, for instance, AMR **11** (1958), Rev. 1843].

G. Capriz, England

3207. Furuhama, S., A dynamic theory of piston-ring lubrication (1st report, Calculation), *Bull. JSME* **2**, 7, 423–428, Aug. 1959.

An analysis of the lubrication of piston rings is presented that accounts for load-carrying capacity where the piston ring speed is near 0, e.g. at TDC, by squeeze action. An equation for load carrying is derived consisting of two terms, one proportional to the sliding velocity and the second proportional to the rate of change of thickness of the oil film. The first corresponds to steady flow hydrodynamics and the second to squeeze film dynamics. The latter effect depends largely on the rate of change of velocity and only slightly on the rate of change of load. The application of the theory is illustrated by numerous examples. Reviewer believes that the value of this paper will be greatly enhanced by the experimental confirmation of the author's theory, the appearance of which is promised in a forthcoming publication.

J. W. Givens, USA

Symposium on friction and wear, edited by R. Davies (Proceedings of the Symposium on Friction and Wear, Detroit, June 1957), Princeton, N. J., D. Van Nostrand Co., Inc., 1959, 191 pp. (Revs. 3208–3215)

3208. Davies, R., A tentative model for the mechanical wear process, 1–15.

An approach to the formulization of models for the mechanical wear process is developed from the following five hypotheses: (a) The rubbing materials receive energy in quanta, all of which are the same size. (b) The quanta of energy are added at moments which are randomly spaced in time. (c) The quanta of energy are added at domains that are randomly spaced over the rubbing surfaces. (d) The quantized energy which is added at the surface diffuses continuously into the material at a known rate. (e) Sufficient energy in any one piece of the material causes that piece to detach itself in the form of a wear particle. No justification is given for hypothesis (a) or (e), although the remaining hypotheses may be qualitatively appreciated from physical considerations. The hypotheses are then treated statistically and an equation evolved which predicts the relative distribution of wear particles of various sizes. This equation does not differ significantly from the log-normal distribution. The statement is made that many experimental data have been successfully fitted to the log-normal distribution but no supporting data or references are given. Reviewer finds difficulty in accepting hypothesis (a) and, in the discussion of the paper, the problem of treatment of subsequent quanta into the same asperity was posed.

F. T. Barwell, England

3209. Drutowski, R. C., Energy losses of balls rolling on plates, 16–35.

Experiments are described in which the lateral force required to cause a ball to roll when loaded between two flat parallel plates was measured by a system employing resistance strain gages. Considerable erratic variations in friction are recorded and the value is shown to be dependent on hardness and surface condition. The variation of friction with load is divisible into two ranges. In the lower range where elastic conditions predominate, the rate of increase with load is considerably less than in the higher range where plastic conditions operate. Support is provided for the contention that the predominant loss of energy in rolling is attributable to hysteresis losses within the material.

F. T. Barwell, England

3210. Coffin, L. F., Jr., Some metallurgical aspects of friction and wear, 36–66.

The nature and extent of damage by rubbing pairs may take many forms but the author is able to generalize his results into two categories, "sliding by shear" and "sliding by welding." In the former case, the separation of asperities which have been forced together takes place at the original interface with little consequential damage. Indeed, the surface may be improved by a mild smoothing action. In sliding by welding, the opposing surfaces are assumed to bond together so effectively at the points of contact that sliding can only take place by tearing of the base metal. This leads to roughened and heavily abraded surfaces. It will be readily appreciated how such factors as miscibility, type of bond and nature of any intermetallic compounds formed may drastically affect the wearing behavior of any combination.

Clearly, the possibility of sliding by shear is increased by contamination of the surfaces, deliberately by lubrication or inadvertently by reaction with the environment. Coffin describes experiments in which the atmosphere surrounding the tests may consist of helium rather than air. In general, the effect of air is shown to be harmful. A particular example was where a lead rider was run on a steel disk. Here, the introduction of oxygen was responsible for transferring the process from sliding by shear to sliding by welding, the presence of oxygen apparently increasing the adhesion at the interface sufficiently to cause fracture to occur within the lead. It is possible that in an oxygen or air atmosphere, the interaction at the interface is between oxides rather than between metals.

Other tests explored the effect of ambient temperature and, in general, transition from sliding to tearing conditions occurred on a critical temperature being reached. Similar experiments in which a lubricant was used showed also transition from one form of wear to another on a critical temperature being reached. This fits in with the general ideas regarding the inception of scuffing, the transition temperature in the case of gears corresponding with Blok's "Flash Temperatures."

F. T. Barwell, England

3211. Goodzeit, C. L., The seizure of metal pairs during boundary lubrication, 67–83.

Experiments are described in which a number of pure metal test pieces are forced against rotating disks while lubricated with kerosene. The conditions of load and speed were such that the kerosene lubricant was relatively ineffective and conditions at failure could be described as clean metal sliding on clean metal. Some important conclusions follow: Metals which are miscible have poor seizure resistance. Of those metals which are immiscible, performance varies from good, through fair to bad. For example, metals which give good performance with steel are gold, cadmium, indium, thalium and lead, and they are all in the "B" sub-group of the periodic table as well as being immiscible with iron. However, the alkali and alkali earth metals including magnesium, calcium and barium, although immiscible with iron gave poor score resistance. This is attributed to a different type of bonding, the alkali metals having a pronounced metallic bonding while the "B" sub-group metals have varying amounts of covalent bonding. The important generalization, "Similar bond types tend to promote seizure, dissimilar bond types tend to resist it" should be of great assistance to engineers and metallurgists engaged in the formulation and selection of bearing metals.

F. T. Barwell, England

3212. Bowden, F. P., Recent experimental studies of solid friction, 84–109.

This lecture, reported verbatim, summarizes the more recent achievements of the author and his colleagues, together with his school, some of which have been reported elsewhere. Effective boundary lubrication must resist, as far as possible, the pressure

which is concentrated at surface irregularities so as to diminish the area of metallic contact. To effectively resist this pressure, the lubricant must behave as a solid. This approach, described as crude and simple by the author, may, however, be taken as the basis of a more sophisticated treatment which may be expected to produce results of a quantitative value.

Temperature measurements were made on materials rubbing together at speeds up to 1500 miles/hour. The melting point of the metal was recorded over a wide range of high sliding speeds but surface melting was shown to be localized and did not lead to the formation of a coherent hydrodynamic film of liquid metal. Bismuth and antimony revealed critical speeds below which the metals took on a fine polish and above which they disintegrated into a fine dust. This behavior is tentatively attributed to the limited rate at which a plastic wave may travel through a metal. If a metal is deformed at a greater rate than dislocations can move, brittle failure will result.

When diamond is rubbed with steel at high speed (500 mph), it is worn away. Hot spots (1000 to 1500 C) are formed which are believed to transform diamond into graphite.

As demonstrated by Savage outgassed graphite at room temperature gives a high coefficient of friction (0.06). Experiments at higher temperatures in vacuum show a falling-off in this value as temperature is raised, a value of about 0.22 being recorded at temperatures approaching 1500 C.

When sliding against metals, iron, nickel and tantalum, a similar behavior is reported except that above 1000 C friction rises to a very high value. This is attributed to the formation of carbides by reaction between the metal and the graphite.

A test is reported in which aluminum is cut with a molybdenum tool with and without the presence of H_2S gas. The gas is shown to produce significant improvement which is attributed to the formation of a layer of molybdenum disulphide at the interface. Possibilities of gas phase lubrication at high temperatures are discussed.

Experiments in which steel spheres roll or slide on well-lubricated rubber are described which show agreement with the hysteresis loss theory unless contact pressures become extremely high.

The paper concludes with illustrations of the direct observation of dislocations. These include observations on platinum phthatocyanine by direct electron microscopy and interference methods where Moiré fringes occasioned by superposition of thin gold and palladium films are illustrated.

F. T. Barwell, England

3213. Zisman, W. A., Friction, durability and wettability properties of monomolecular films on solids, 110–148.

Author describes experiments wherein the friction was measured between a 1/2-inch diameter stainless steel ball sliding at a speed of 0.01 cm/sec and a glass plate when lubricated by boundary layers of various substances. The normal load between the sphere and the plate could be varied from a few grams to 9000 grams but the coefficient of friction was found to be substantially invariant with load.

The action of a lubricant may be either by chemical reaction with the surface, hydrodynamic behavior or due to physical adsorption. The pioneer work of Hardy on this latter topic has not always been confirmed by subsequent workers but in this extremely thorough investigation, the main premises of Hardy's work have been confirmed.

A major advance represented by the author's work relates to the method of depositing a monomolecular film onto the test piece. Early workers had transferred films from water surfaces in a Langmuir trough but the author has developed means for absorbing these films from solutions and for completely separating the resulting film-coated solid from the solvent. The effect of the means used to produce the monomolecular layer are discussed in the paper, two aforementioned methods being compared with films deposited from the vapor phase. A great deal of data is given relating to a large number of chemical substances.

F. T. Barwell, England

3214. Rabinowicz, E., A study of the stick-slip process, 149–164.

The initiation of oscillatory behavior of sliding surfaces is discussed and the author shows how this condition may arise from variations in frictional behavior of different areas of a surface. He states that effective lubrication of a steel surface requires about 10^{-6} cm of a solid lubricant which may be a soap formed by reaction between active constituents of the lubricant and the surface itself. This is probably a fairer representation of the action of many boundary lubricants in practice than any explanation based on the adsorption of monomolecular layers. As has been shown by earlier workers, stick-slip phenomena can usually be overcome by the provision of adequate damping within the system and, indeed, by suitable adjustment of the stiffness and relative velocity thereof.

F. T. Barwell, England

3215. Gwathmey, A. T., and Dyer, L. D., Cohesion between two oriented single crystals of copper, 165–182.

Experiments are described in which oriented single cyrstals are forced together under carefully controlled environmental conditions and then separated. They were carried out in an atmosphere of hydrogen at temperatures ranging from 200 to 800 C. The consequent damage was then studied in detail and, as illustrated, consisted of a smooth central area surrounded by corrugations which are described as "fingers." The direction of these fingers was dependent on the relative orientation of the crystal planes of the original specimens and their extent depended on the time of loading. The growth of these fingers is attributed to anisotropy of surface energy. When the test pieces were allowed to cool before separation, the central area was shown to possess cavities whose shape depended on the orientation of the crystals. This observation was explained by the concentration of vacancies. Because ultimately, certain forms of wear may be expected to originate from the crystals of metals being forced together under a high local temperature arising from friction, these experiments must be relevant to the problem.

F. T. Barwell, England

End of symposium

Letters to the Editor

3216. Re: AMR **12**(May 1959), Rev. 2302: **Cohen, M. J., Stress and strain in spinning paraboloid dishes,** ASME Semiann. Meet., Detroit, Mich., June 1958. Pap. 58-SA-8, 8 pp.

"The equation of compatibility of strains used, with reservations, in the paper is quite suitable for paraboloid dishes of small apertures and not only in the limiting case. The critical dish parameter is $R\alpha^2/h$, where R is the radius, h the thickness and α the semi-aperture of the dish. For "small" values of $R\alpha^2/h$, ($R\alpha^2/h < 1/2$) the equation of compatibility of strains used is valid. The example used to illustrate the method (corresponding to $R\alpha^2/h = 6$) was, however, unjudicious and hence possibly misleading."

M. J. Cohen, England

3217. Re: AMR **13** (1960), Rev. 1071: **Pistiner, J. S., On-off control system for attitude stabilization of a space vehicle,** *ARS J.* **29**, 4, 283–289, Apr. 1959.

Reviewer's name should have been printed R. Oldenburger, not Oldenberger. The editors regret this error.

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